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[Document Name] SPECIFICATION

[Title of the Invention] INFORMATION RECORDING MEDIUM, METHOD FOR PRODUCING THE SAME, AND RECORDING/REPRODUCING METHOD USING THE SAME

[Claims]

[Claim 1] An information recording medium in which a first information layer including a first recording layer that is transformed in phase reversibly between a crystal phase and an amorphous phase by irradiation with a high-energy laser beam and a second information layer including a second recording layer that is transformed in phase reversibly between a crystal phase and an amorphous phase by irradiation with a high-energy laser beam are formed via an intermediate layer, wherein the first recording layer contains Ge, Sn, Sb and Te, and assuming that a film thickness of the first recording layer is d (nm), $d \leq 9$ nm is satisfied.

[Claim 2] The information recording medium according to claim 1, wherein a composition of the first recording layer is represented by a composition formula: $(Ge\text{–}Sn)_aSb_bTe_{3+a}$, where a is in a range of $2 \leq a \leq 22$ and b is in a range of $2 \leq b \leq 4$.

[Claim 3] The information recording medium according to claim 2, wherein a composition of the first recording layer is represented by a composition formula: $(Ge\text{–}Sn)_aSb_bTe_{3+a}$, where a is in a range of $2 \leq a \leq 10$ and b is in a range of $2 \leq b \leq 4$.

[Claim 4] The information recording medium according to claim 2 or 3, wherein a composition of the first recording layer is represented by a composition formula: $(Ge\text{–}Sn)_aSb_bTe_{3+a}$, where $b = 2$.

[Claim 5] The information recording medium according to any one of claims 2 to 4, wherein, assuming that a concentration of Ge is x (atomic %)

and a concentration of Sn is y (atomic %),

$x + y = [100a/(3 + 2a + b)]$ is held, and y is in a range of 0 atomic % < $y \leq 25$ atomic %.

[Claim 6] The information recording medium according to claim 1, wherein, assuming that a transmittance of the first information layer in a case where the first recording layer is in a crystal phase is Tc (%), a transmittance of the first information layer in a case where the first recording layer is in an amorphous phase is Ta (%), and a wavelength of a laser beam for recording, erasing, or reproducing information of the first information layer is λ (nm),

in 390 nm $\leq \lambda \leq$ 430 nm,

$40\% \leq (Tc + Ta)/2$ is satisfied.

[Claim 7] The information recording medium according to any one of claims 1 to 6, wherein the first information layer has a configuration in which at least a first lower protective layer, the first recording layer, a first upper protective layer, and a first reflective layer are stacked on a first substrate in this order.

[Claim 8] The information recording medium according to any one of claims 1 to 6, wherein the first information layer has a configuration in which at least a first reflective layer, a first upper protective layer, the first recording layer, and a first lower protective layer are stacked on an intermediate layer in this order.

[Claim 9] The information recording medium according to claim 7 or 8, wherein at least one interface layer of a first lower interface layer between the first lower protective layer and the first recording layer, a first upper interface layer between the first upper protective layer and the first recording layer, and a first interface layer between the first upper protective

layer and the first reflective layer is provided.

[Claim 10] The information recording medium according to any one of claims 7 to 9, wherein a first uppermost protective layer is formed between the intermediate layer and the first reflective layer.

[Claim 11] The information recording medium according to claim 10, wherein a first uppermost interface layer is provided between the first reflective layer and the first uppermost protective layer.

[Claim 12] The information recording medium according to any one of claims 7 to 11, wherein assuming that a film thickness of the first reflective layer is d1 (nm), 5 nm $\leq$ d1 $\leq$ 15 nm is satisfied.

[Claim 13] The information recording medium according to any one of claims 7 to 12, wherein assuming that a thickness of the first substrate is d2 (μm), 10 μm $\leq$ d2 $\leq$ 700 μm is satisfied.

[Claim 14] The information recording medium according to claim 1, wherein the second information layer has a configuration in which at least a second reflective layer, a second upper protective layer, a second recording layer, and a second lower protective layer are stacked on a second substrate in this order.

[Claim 15] The information recording medium according to claim 14, wherein at least one interface layer of a second lower interface layer between the second lower protective layer and the second recording layer, a second upper interface layer between the second upper protective layer and the second recording layer, and a second interface layer between the second upper protective layer and the second reflective layer is provided.

[Claim 16] The information recording medium according to claim 14 or 15, wherein assuming that a thickness of the second substrate is d3 (μm), 500 μm $\leq$ d3 $\leq$ 1300 μm is satisfied.

[Claim 17] A method for producing an information recording medium comprising a first information layer forming step including a first recording layer forming step of forming a first recording layer that is transformed in phase reversibly between a crystal phase and an amorphous phase by irradiation with a high-energy laser beam and a second information layer forming step including a second recording layer forming step of forming a second recording layer that is transformed in phase reversibly between a crystal phase and an amorphous phase by irradiation with a high-energy laser beam, wherein the first recording layer forming step uses a base material made of GeSnSbTe, and assuming that a film thickness of the first recording layer is d (nm), the first recording layer is formed in a range of $d \leq 9$ nm.

[Claim 18] The method for producing an information recording medium according to claim 17, wherein the first recording layer forming step and the second recording layer forming step use argon gas or krypton gas, or a mixed gas containing at least one of nitrogen gas and oxygen gas, and argon gas or krypton gas.

[Claim 19] The method for producing an information recording medium according to claim 17 or 18, wherein in the first recording layer forming step, a film formation rate is 0.1 nm/sec. to 10 nm/sec.

[Claim 20] The method for producing an information recording medium according to any one of claims 17 to 19, wherein the first information layer forming step includes at least a first lower protective layer forming step of forming a first lower protective layer on a first substrate, a first recording layer forming step, a first upper protective layer forming step of forming a first upper protective layer, and a first reflective layer forming step of forming a first reflective layer in this order.

[Claim 21] The method for producing an information recording medium according to any one of claims 17 to 19, wherein the first information layer forming step includes at least a first reflective layer forming step of forming a first reflective layer on an intermediate layer, a first upper protective layer forming step, a first recording layer forming step, and a first lower protective layer forming step in this order.

[Claim 22] The method for producing an information recording medium according to claim 20 or 21, wherein at least one interface layer forming step of a first lower interface layer forming step of forming a first lower interface layer between the first lower protective layer forming step and the first recording layer forming step, a first upper interface layer forming step of forming a first upper interface layer between the first upper protective layer forming step and the first recording layer forming step, and a first interface layer forming step of forming a first interface layer between the first upper protective layer forming step and the first reflective layer forming step is provided.

[Claim 23] The method for producing an information recording medium according to claim 20, wherein a first uppermost protective layer forming step of forming a first uppermost protective layer on the first reflective layer is provided.

[Claim 24] The method for producing an information recording medium according to claim 21, wherein a first uppermost protective layer forming step of forming a first uppermost protective layer on an intermediate layer is provided.

[Claim 25] The method for producing an information recording medium according to claim 23 or 24, wherein the first uppermost interface layer forming step is provided between the first reflective layer forming step

and the first uppermost protective layer forming step.

[Claim 26] The method for producing an information recording medium according to any one of claims 20 to 25, wherein in the first reflective layer forming step, assuming that a film thickness of the first reflective layer is d1 (nm), the first reflective layer is formed in a range of 5 nm $\leq$ d1 $\leq$ 15 nm.

[Claim 27] The method for producing an information recording medium according to any one of claims 20 to 26, wherein assuming that a thickness of the first substrate is d2 (μm), 10 μm $\leq$ d2 $\leq$ 700 μm is satisfied.

[Claim 28] The method for producing an information recording medium according to claim 17 or 18, wherein the second information layer forming step includes at least a second reflective layer forming step of forming a second reflective layer on the second substrate, a second upper protective layer forming step of forming a second upper protective layer, a second recording layer forming step, and a second lower protective layer forming step of forming a second lower protective layer in this order.

[Claim 29] The method for producing an information recording medium according to claim 28, wherein at least one interface layer forming step of a second lower interface layer forming step of forming a second lower interface layer between the second lower protective layer forming step and the second recording layer forming step, a second upper interface layer forming step of forming a second upper interface layer between the second upper protective layer forming step and the second recording layer forming step, and a second interface layer forming step of forming a second interface layer between the second upper protective layer forming step and the second reflective layer forming step is provided.

[Claim 30] The method for producing an information recording

medium according to claim 28 or 29, wherein assuming that a thickness of the second substrate is d3 (μm), 500 μm ≤ d3 ≤ 1200 μm is satisfied.

[Claim 31] A method for recording/reproducing information with respect to the information recording medium according to claim 1, wherein a laser beam is incident from a first information layer side, information is recorded/reproduced with respect to a second information layer with the laser beam having passed through the first information layer, and a wavelength λ (nm) of the laser beam is in a range of 390 nm ≤ λ ≤ 430 nm.

[Claim 32] The method for recording/reproducing information with respect to an information recording medium according to claim 31, wherein a linear velocity of the information recording medium in recording/reproducing information is in a range of 1 m/second to 50 m/second.

[Claim 33] The method for recording/reproducing information with respect to an information recording medium according to claim 31 or 32, wherein a numerical aperture NA of an objective lens in recording/reproducing information is 0.4 to 1.1.

[Claim 34] The method for recording/reproducing information with respect to an information recording medium according to any one of claims 31 to 33, wherein the first information layer records/reproduces information between grooves (groove surface that is closer when seen from a laser beam, also referred to as a groove).

[Claim 35] The method for recording/reproducing information with respect to an information recording medium according to any one of claims 31 to 33, wherein the first information layer records/reproduces information on grooves (groove surface that is placed farther when seen from a laser beam, also referred to as a land).

[Claim 36] The method for recording/reproducing information with respect to an information recording medium according to any one of claims 31 to 33, wherein the first information layer records/reproduces information between grooves and on the grooves.

[Claim 37] The method for recording/reproducing information with respect to an information recording medium according to any one of claims 31 to 36, wherein the second information layer records/reproduces information between grooves.

[Claim 38] The method for recording/reproducing information with respect an information recording medium according to any one of claims 31 to 36, wherein the second information layer records/reproduces information on grooves.

[Claim 39] The method for recording/reproducing information with respect to an information recording medium according to any one of claims 31 to 36, wherein the second information layer records/reproduces information between grooves and on grooves.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to an information recording medium for optically recording, erasing, rewriting, and reproducing information, a method for producing the same, and a method for recording/reproducing information with respect to the same.

[0002]

[Prior Art]

In a phase-change information recording medium, information is recorded, erased and rewritten using a recording layer that is transformed

in phase reversibly between a crystal phase and an amorphous phase. When this recording layer is irradiated with a high power laser beam and then is cooled rapidly, a portion thus irradiated is changed to be in an amorphous phase, whereby a recording mark is formed. When an amorphous portion of the recording layer is irradiated with a low power laser beam to increase a temperature and then is cooled slowly, the portion thus irradiated is changed to be in a crystal phase, whereby the previous information is erased. Therefore, in the phase-change information recording medium, the recording layer is irradiated with laser beams having powers modulated between a high power level and a low power level, whereby new information is rewritten while previous information is being erased.

[0003]

In recent years, in order to increase the capacity of an information recording medium, the following techniques have been studied: a high-density recording technique of recording a smaller recording mark at a shorter interval using a violet laser beam, a high-density recording technique of recording a smaller recording mark by making a substrate thinner on a recording/reproducing side while using a lens with a large numerical aperture, and a technique of recording/reproducing information with respect to two information layers from one side to substantially double the capacity disclosed in JP 12–36130 A.

[0004]

In order to put the technique using a blue violet laser and a technique using a high-NA lens into practical use, it is required to perform not only the development of a laser and a lens, but also the development of an information recording medium capable of recording a smaller mark in a

satisfactory shape. In order to record a small recording mark on a recording layer at a shorter interval, a time during which the recording layer is irradiated with a laser beam becomes relatively short. Thus, as a crystallization speed of a recording layer, there is a demand for the development of a material faster than a conventional example. Furthermore, recording/reproducing information with respect to two information layers from one side (two-layer information recording medium) refers to recording/reproducing information with respect to an information layer (second information layer) farthest from a laser with a laser beam having passed through an information layer (first information layer) placed closest to the laser, so that the first information layer needs to have a sufficient transmittance. Assuming that the transmittance of the first information layer in the case where the first recording layer is in a crystal phase is Tc(%), and the transmittance in the case where the first recording layer is an amorphous phase is Ta(%), it is desired that $40 \leq (Tc + Ta)/2$ is satisfied in a wavelength region of a laser beam for recording/reproducing. For this purpose, it is necessary to make the first recording layer to be very thin (i.e., about 6 nm). As the recording layer becomes thinner, the absolute number of atoms contained therein decreases. Therefore, due to the decrease in a crystal core formed in crystallization and the reduction in a distance in which atoms can move in crystallization, the crystallization speed tends to decrease relatively even with the same material. More specifically, as the recording layer is thinner, a crystal phase is unlikely to be formed, which decreases an erasure ratio. It becomes more difficult to erase previously recorded information and record new information.

[0005]

Conventionally, as a phase-change material for a recording layer,

Ge–Sb–Te system materials having a high crystallization speed, being excellent in repeated rewriting performance, and having high reliability have been used, and a phase-change optical disk for a personal computer and an image has been commercialized. Among the Ge–Sb–Te system materials, a pseudo binary composition $GeTe$-Sb_2Te_3 has the highest crystallization speed. It is found by the experiment of the inventors that assuming $(GeTe) : (Sb_2Te_3) = a : 1$, a stoichiometric composition is present in a = 0.5, 1, 2, and in particular, a $Ge_2Sb_2Te_5$ composition (a = 2) has very excellent recording/erasing performance. For example, according to (M. Uno, K. Nagata and N. Yamada, "Thinning Limitation of Ge-Sb-Te Recording Film for High Transmittance Media", Proc. of PCO'99. 83-88), it is reported that, according to a recording/reproducing test with a red laser having a wavelength of 660 nm, in high linear velocity recording of 9 m/s, even when a Ge–Sb–Te recording layer is set to have a very small thickness (i.e., 6 nm), a satisfactory erasure ratio (i.e., 30 dB) is obtained. The feasibility of a two-layer information recording medium with a red laser using this technique has been found.

[0006]

[Problems to be Solved by the Invention]

The inventors conducted a recording/reproducing experiment of a first information layer using a blue violet laser having a wavelength of 405 nm, with the aim of further increasing the density based on the above experimental results. It is found that, in $(GeTe):(Sb_2Te_3) = 1:1$, the crystallization speed is higher when a is smaller, and the optical change becomes larger when a is larger. The optical change as used herein refers to a change in a refractive index between a crystal phase and an amorphous phase. The composition of a recording layer was checked if satisfactory

recording erasure performance was obtained at a film thickness of 6 nm. Consequently, when $a \leq 2$, the optical change was small, so that a signal amplitude was not obtained. When $a > 2$, although a signal amplitude became large, due to the insufficient crystallization speed, an erasure ratio was insufficient (about 10 dB). In the first recording layer of 6 nm, only an erasure ratio of about 10 dB was obtained, and in a Ge–Sb–Te system material, it was difficult to realize a two-layer information recording medium with a blue ultraviolet laser.

[0007]

The present invention solves the above-mentioned problem, and its object is to obtain satisfactory recording and erasing characteristics by setting a first recording layer of a two-layered information recording medium to be very thin in higher density recording, and ensuring a high transmittance with a laser having a wavelength shorter than that of a conventional example.

[0008]

[Means for Solving the Problems]

In order to solve the above problem, in an information recording medium of the present invention, a first information layer including a first recording layer that is transformed in phase reversibly between a crystal phase and an amorphous phase by irradiation with a high-energy laser beam and a second information layer including a second recording layer that is transformed in phase reversibly between a crystal phase and an amorphous phase by irradiation with a high-energy laser beam are formed via an intermediate layer, wherein the first recording layer contains Ge, Sn, Sb and Te, and assuming that a film thickness of the first recording layer is d (nm), $d \leq 9$ nm is satisfied. The composition of the first recording layer is

represented by a composition formula: $(Ge-Sn)_aSb_bTe_{3+a}$, and a is in a range of $2 \leq a \leq 22$ and b is in a range of $2 \leq b \leq 4$. It is preferable that a is in a range of $2 \leq a \leq 10$, and when $b = 2$, a compound line represented by a composition formula: $(Ge-Sn)_aSb_2Te_{3+a}$, and having a highest crystallization speed is obtained. Assuming that the concentration of Ge is x (atomic %), and the concentration of Sn is y (atomic %), $x + y = [100a/(3 + 2a + b)]$ is held, and y is in a range of 0 atomic % $< y \leq 25$ atomic %. Assuming that the transmittance of the first information layer is Tc (%) in the case where the first recording layer is in a crystal phase, and the transmittance of the first information layer is Ta(%) in the case where the first recording layer is in an amorphous phase, and the wavelength of a laser beam for recording, erasing, or reproducing information of the first information layer is λ (nm), $40\% \leq (Tc + Ta)/2$ is satisfied in 390 nm $\leq \lambda \leq$ 430 nm.

[0009]

Furthermore, in the information recording medium of the present invention, the first information layer has a configuration in which at least a first lower protective layer, the first recording layer, a first upper protective layer, and a first reflective layer are stacked on a first substrate in this order. Alternatively, the first information layer has a configuration in which at least a first reflective layer, a first upper protective layer, the first recording layer, and a first lower protective layer are stacked on an intermediate layer in this order. At least one interface layer of a first lower interface layer between the first lower protective layer and the first recording layer, a first upper interface layer between the first upper protective layer and the first recording layer, and a first interface layer between the first upper protective layer and the first reflective layer is provided. The first uppermost protective layer may be formed between the intermediate layer and the first

reflective layer, and the first uppermost interface layer may be provided between the first reflective layer and the first uppermost protective layer. Assuming that the film thickness of the first reflective layer is d1 (nm), 5 nm ≤ d1 ≤ 15 nm. When the thickness of the first substrate is d2 (μm), 10 μm ≤ d2 ≤ 700 μm.

[0010]

The second information layer has a configuration in which at least a second reflective layer, a second upper protective layer, a second recording layer, and a second lower protective layer are stacked on a second substrate in this order. At least one interface layer of a second lower interface layer between the second lower protective layer and the second recording layer, a second upper interface layer between the second upper protective layer and the second recording layer, and a second interface layer between the second upper protective layer and the second reflective layer is provided. Assuming that the thickness of the second substrate is d3 (μm), 500 μm ≤ d3 ≤ 1300 μm is satisfied.

[0011]

Furthermore, a method for producing an information recording medium includes a first information layer forming step including a first recording layer forming step of forming a first recording layer that is transformed in phase reversibly between a crystal phase and an amorphous phase by irradiation with a high-energy laser beam and a second information layer forming step including a second recording layer forming step of forming a second recording layer that is transformed in phase reversibly between a crystal phase and an amorphous phase by irradiation with a high-energy laser beam, wherein the first recording layer forming step uses a base material made of Ge, Sn, Sb and Te, and assuming that a

film thickness of the first recording layer is d (nm), the first recording layer is formed in a range of d ≤ 9 nm.

[0012]

The first recording layer forming step and the second recording layer forming step use argon gas or krypton gas, or a mixed gas containing at least one of nitrogen gas and oxygen gas, and argon gas or krypton gas. In the first recording layer forming step, the film formation rate is 0.1 nm/sec. to 10 nm/sec.

[0013]

The first information layer forming step includes at least a first lower protective layer forming step of forming a first lower protective layer on a first substrate, a first recording layer forming step, a first upper protective layer forming step of forming a first upper protective layer, and a first reflective layer forming step of forming a first reflective layer in this order. A first uppermost protective layer forming step may be provided after the first reflective layer forming step (hereinafter, in the present specification, the order in which the lower protective layer forming step comes first in the film forming step in this manner will be described as a forward step).

[0014]

Alternatively, the first information layer forming step includes at least a first reflective layer forming step of forming a first reflective layer on an intermediate layer, a first upper protective layer forming step, a first recording layer forming step, and a first lower protective layer forming step in this order. A first uppermost protective layer forming step of forming a first uppermost protective layer on the intermediate layer may be provided before the first reflective layer forming step (hereinafter, in present the

specification, the order in which the lower protective layer forming step comes last in the film forming step in this manner will be described as a backward step).

[0015]

In any of the forward step and the backward step, at least one interface layer forming step of a first lower interface layer forming step of forming a first lower interface layer between the first lower protective layer forming step and the first recording layer forming step, a first upper interface layer forming step of forming a fist upper interface layer between the first upper protective layer forming step and the first recording layer forming step, and a first interface layer forming step of forming a first interface layer between the first upper protective layer forming step and the first reflective layer forming step is provided. Furthermore, a first uppermost interface layer forming step may be provided between the first reflective layer forming step and the first uppermost protective layer forming step.

[0016]

In the first reflective layer forming step, assuming that a film thickness of the first reflective layer is d1 (nm), the first reflective layer is formed in a range of 5 nm $\leq$ d1 $\leq$ 15 nm. Assuming that a thickness of the first substrate is d2 (μm), a substrate satisfying 10 μm $\leq$ d2 $\leq$ 700 μm is used.

[0017]

The second information layer forming step includes at least a second reflective layer forming step of forming a second reflective layer on the second substrate, a second upper protective layer forming step, a second recording layer forming step, and a second lower protective layer forming

step in this order (backward step). At least one interface layer forming step of a second lower interface layer forming step of forming a second lower interface layer between the second lower protective layer forming step and the second recording layer forming step, a second upper interface layer forming step of forming a second upper interface layer between the second upper protective layer forming step and the second recording layer forming step, and a second interface layer forming step of forming a second interface layer between the second upper protective layer forming step and the second reflective layer forming step is provided. Assuming that a thickness of the second substrate is d3 (μm), a substrate satisfying 500 μm ≤ d3 ≤ 1200 μm is used.

[0018]

Furthermore, according to a method for recording/reproducing information with respect to the information recording medium of the present invention, a laser beam is incident from a first information layer side, information is recorded/reproduced with respect to a second information layer with the laser beam having passed through the first information layer, and a wavelength λ (nm) of the laser beam is in a range of 390 nm ≤ λ ≤ 430 nm. A linear velocity of the information recording medium in recording/reproducing information is in a range of 1 m/second to 50 m/second. A numerical aperture NA of an objective lens in recording/reproducing information is 0.4 to 1.1. In the first information layer and the second information layer, information may be recorded between grooves or on grooves, or between grooves and on grooves.

[0019]

In an information recording medium recited in claim 1, a first information layer including a first recording layer that is transformed in

phase reversibly between a crystal phase and an amorphous phase by irradiation with a high-energy laser beam and a second information layer including a second recording layer that is transformed in phase reversibly between a crystal phase and an amorphous phase by irradiation with a high-energy laser beam are formed via an intermediate layer, wherein the first recording layer contains Ge, Sn, Sb and Te, and assuming that a film thickness of the first recording layer is d (nm), $d \leq 9$ nm is satisfied. Thus, even when the first recording layer is prescribed to be very thin, the first information layer has a function of obtaining satisfactory recording and erasing characteristics with a blue violet laser. Sn added to the Ge–Sb–Te tertiary composition has a function of enhancing crystallization ability. Furthermore, when the first recording layer satisfies $d \leq 9$ nm, the first information layer has a function of obtaining a high transmittance.

[0020]

In an information recording medium recited in claims 2 to 4, a composition of the first recording layer is represented by a composition formula: $(Ge\text{–}Sn)_aSb_bTe_{3+a}$, where a is in a range of $2 \leq a \leq 22$ and b is in a range of $2 \leq b \leq 4$. Thus, even when the first recording layer is prescribed to be very thin, satisfactory recording and erasing characteristics can be obtained with a blue violet laser. When $a < 2$, an optical change is small and a signal amplitude is insufficient in a blue violet wavelength region. When $22 < a$, although a signal amplitude increases, a melting point increases and a crystallization speed decreases. Therefore, the range of $2 \leq a \leq 22$ is preferable. Regarding the range of b, when $b < 2$, Sb is insufficient, so that a Sb_2Te_3 compound cannot be formed, and Te having a low melting point is likely to be precipitated in reversible phase transformation between a crystal phase and an amorphous phase. When b

= 2, there is a function that a compound line represented by a composition formula: $(Ge-Sn)_aSb_2Te_{3+a}$, and having a highest crystallization speed of $a[(Ge-Sn)Te]-Sb_2Te_3$ is obtained. Furthermore, when $2 < b \leq 4$, a composition is obtained which contains more Sb (excess Sb), compared with the compound line having a highest crystallization speed of $a[(Ge-Sn)Te]-Sb_2Te_3$. The excess Sb has a function of increasing a crystallization temperature to obtain thermal stability of a recording mark, and a function of suppressing the movement of a material caused by repeated recording, as amorphous Sb, without entering a crystal lattice. When a is in a range of $2 \leq a \leq 10$, there is a function that a first information layer excellent in repeated recording is obtained.

[0021]

In an information recording medium recited in claim 5, assuming that a concentration of Ge is x (atomic %) and a concentration of Sn is y (atomic %), $x + y = [100a/(3 + 2a + b)]$ is held, and y is in a range of 0 atomic % < y ≤ 20 atomic %. Thus, even when the first recording layer is prescribed to be very thin, a sufficient erasure ratio can be obtained by recording with a blue violet laser. By adjusting the excess Sb amount (b-value) and the Sn concentration (y-value), the crystallization speed and the crystallization temperature can be regulated. When only Sn is added, the crystallization speed increases and the crystallization temperature decreases. However, when Sb and Sn are added, the crystallization speed can be enhanced without decreasing the crystallization temperature. When the concentration of Sn among (Ge–Sn) is too large, the change in a refractive index between the crystal phase and the amorphous phase of the first recording layer becomes small, whereby recording characteristics decrease. The preferable range of y is 0 atomic % < y ≤ 11 atomic % when a

= b = 2, and 3 atomic % < y ≤ 15 atomic % when a = 2 and b = 4. Furthermore, the preferable range of y is 0 atomic % < y ≤ 22 atomic % when a = 22 and b = 2, and 3 atomic % < y ≤ 25 atomic % when a = 22 and b = 4. Thus, it is preferable that y is in a range of 0 atomic % < y ≤ 25 atomic %.

[0022]

In an information recording medium recited in claim 6, assuming that a transmittance of the first information layer in a case where the first recording layer is in a crystal phase is Tc (%), a transmittance of the first information layer in a case where the first recording layer is in an amorphous phase is Ta (%), and a wavelength of a laser beam for recording, erasing, or reproducing information of the first information layer is λ (nm), in 390 nm ≤ λ ≤ 430 nm, 40% ≤ (Tc + Ta)/2 is satisfied. Thus, a laser beam sufficient for recording and erasing reaches the second information layer, and satisfactory recording and erasing characteristics are obtained even in the second information layer.

[0023]

In the information recording medium recited in claim 7, the first information layer has a configuration in which at least a first lower protective layer, the first recording layer, a first upper protective layer, and a first reflective layer are stacked on a first substrate in this order. Thus, the reflectivity, recording sensitivity, and erasure sensitivity of the first information layer can be optimized in accordance with the recording, erasing, and reproducing conditions.

[0024]

In the information recording medium recited in claim 8, the first information layer has a configuration in which at least a first reflective layer,

a first upper protective layer, the first recording layer, and a first lower protective layer are stacked on an intermediate layer in this order. Thus, the reflectivity, recording sensitivity, and erasure sensitivity of the first information layer can be optimized in accordance with the recording, erasing, and reproducing conditions.

[0025]

In the information recording medium recited in claim 9, at least one interface layer of a first lower interface layer between the first lower protective layer and the first recording layer, a first upper interface layer between the first upper protective layer and the first recording layer, and a first interface layer between the first upper protective layer and the first reflective layer is provided. Thus, the diffusion of atoms between the protective layer and the recording layer or between the protective layer and the reflective layer in repeated recording and high-temperature high-humidity recording is prevented, whereby repetition characteristics and reliability are enhanced.

[0026]

In the information recording medium recited in claim 10, a first uppermost protective layer is formed between the intermediate layer and the first reflective layer. Thus, an optical function of increasing the transmittances Tc (%) and Ta (%) of the first information layer is obtained.

[0027]

In the information recording medium recited in claim 11, a first uppermost interface layer is provided between the first reflective layer and the first uppermost protective layer. Thus, the diffusion of atoms between the reflective layer and the protective layer is prevented to enhance reliability.

[0028]

In the information recording medium recited in claim 12, assuming that a film thickness of the first reflective layer is d1 (nm), 5 nm $\leq$ d1 $\leq$ 15 nm is satisfied. Thus, an optical function of enhancing the transmittance Tc (%), Ta (%) of the first information layer, and a function of diffusing heat generated in the first recording layer rapidly to facilitate the formation of an amorphous state are obtained. The first information layer would not have a sufficient reflectivity without the first reflective layer. Furthermore, in the case of providing the first reflective layer, when the first reflective layer is thin, a heat diffusion function is insufficient. When the first reflective layer is large, the transmittance of the first information layer becomes insufficient. Therefore, the range of 5 nm $\leq$ d1 $\leq$ 15 nm is preferable.

[0029]

In the information recording medium recited in claim 13, assuming that a thickness of the first substrate is d2 (μm), 10 μm $\leq$ d2 $\leq$ 700 μm is satisfied. Thus, the length of a recording mark and a region between the recording marks can be optimized in accordance with the groove shape of a first substrate and recording, erasing, and reproducing conditions by changing the numerical aperture (NA) of an objective lens. As the substrate is thinner, the NA can be increased, whereby a laser beam can be narrowed. For example, in the case where d2 = 100 μm, satisfactory recording and erasing characteristics were confirmed at NA = 0.85. Furthermore, in the case where d2 = 600 μm, satisfactory recording and erasing characteristics were confirmed at NA = 0.6.

[0030]

In the information recording medium recited in claim 14, the second information layer has a configuration in which at least a second reflective

layer, a second upper protective layer, a second recording layer, and a second lower protective layer are stacked on a second substrate in this order. Thus, recording, erasing, or reproducing can be performed from the first information layer side.

[0031]

In the information recording medium recited in claim 15, at least one interface layer of a second lower interface layer between the second lower protective layer and the second recording layer, a second upper interface layer between the second upper protective layer and the second recording layer, and a second interface layer between the second upper protective layer and the second reflective layer is provided. Thus, the diffusion of atoms between the protective layer and the recording layer or between the protective layer and the reflective layer in repeated recording and high-temperature high-humidity recording is prevented, whereby repetition characteristics and reliability are enhanced.

[0032]

In the information recording medium recited in claim 16, assuming that a thickness of the second substrate is d3 (μm), 500 μm $\leq$ d3 $\leq$ 1300 μm is satisfied. Thus, the length of a recording mark and a region between the recording marks can be optimized in accordance with the groove shape of a second substrate and recording, erasing, and reproducing conditions by changing the NA of an objective lens. In the case where the first substrate is about 100 μm, the second substrate is about 1100 μm, and in the case where the first substrate is about 600 μm, the second substrate is also about 600 μm. In this manner, the thicknesses of the first and second substrates are selected and adjusted so that the total thickness of the information recording medium becomes about 1200 μm.

[0033]

A method for producing an information recording medium recited in claim 17 includes a first information layer forming step including a first recording layer forming step of forming a first recording layer that is transformed in phase reversibly between a crystal phase and an amorphous phase by irradiation with a high-energy laser beam and a second information layer forming step including a second recording layer forming step of forming a second recording layer that is transformed in phase reversibly between a crystal phase and an amorphous phase by irradiation with a high-energy laser beam, wherein the first recording layer forming step uses a base material made of Ge–Sn–Sb–Te, and assuming that a film thickness of the first recording layer is d (nm), the first recording layer is formed in a range of $d \leq 9$ nm. Thus, even when the first recording layer is prescribed to be very thin, a first information layer can be produced in which satisfactory recording and erasing characteristics can be obtained with a blue violet laser.

[0034]

According to the method for producing an information recording medium recited in claim 18, the first recording layer forming step and the second recording layer forming step use argon gas or krypton gas, or a mixed gas containing at least one of nitrogen gas and oxygen gas, and argon gas or krypton gas. Thus, a first information layer and a second information having excellent repeated recording can be produced.

[0035]

According to the method for producing an information recording medium recited in claim 19, in the first recording layer forming step, a film formation rate is 0.1 nm/sec. to 10 nm/sec. Thus, the film thickness of the

first recording layer varies less, and a first recording layer can be produced within a short film formation period with satisfactory productivity.

[0036]

According to the method for producing an information recording medium recited in claim 20, the first information layer forming step includes at least a first lower protective layer forming step of forming a first lower protective layer on a first substrate, a first recording layer forming step, a first upper protective layer forming step of forming a first upper protective layer, and a first reflective layer forming step of forming a first reflective layer in this order. Thus, a first information layer can be produced in which the reflectivity, recording sensitivity, and erasure sensitivity of the first information layer can be optimized in accordance with the recording, erasing, and reproducing conditions.

[0037]

According to the method for producing an information recording medium recited in claim 21, the first information layer forming step includes at least a first reflective layer forming step of forming a first reflective layer on an intermediate layer, a first upper protective layer forming step, a first recording layer forming step, and a first lower protective layer forming step in this order. Thus, a first information layer can be produced in which the reflectivity, recording sensitivity, and erasure sensitivity of the first information layer can be optimized in accordance with the recording, erasing, and reproducing conditions.

[0038]

According to the method for producing an information recording medium recited in claim 22, at least one interface layer forming step of a first lower interface layer forming step of forming a first lower interface

layer between the first lower protective layer forming step and the first recording layer forming step, a first upper interface layer forming step of forming a first upper interface layer between the first upper protective layer forming step and the first recording layer forming step, and a first interface layer forming step of forming a first interface layer between the first upper protective layer forming step and the first reflective layer forming step is provided. Thus, the diffusion of atoms between the protective layer and the recording layer or between the protective layer and the reflective layer in repeated recording and high-temperature high-humidity recording is prevented, whereby a first information layer having high repetition characteristics and reliability can be produced.

[0039]

According to the method for producing an information recording medium recited in claim 23, a first uppermost protective layer forming step of forming a first uppermost protective layer on the first reflective layer is provided. Thus, a first information layer with high transmittances Tc(%) and Ta(%) can be produced.

[0040]

According to the method for producing an information recording medium recited in claim 24, a first uppermost protective layer forming step of forming a first uppermost protective layer on an intermediate layer is provided. Thus, a first information layer with transmittances Tc(%) and Ta(%) can be produced.

[0041]

According to the method for producing an information recording medium recited in claim 25, the first uppermost interface layer forming step is provided between the first reflective layer forming step and the first

uppermost protective layer forming step. Thus, a first information layer with high reliability can be produced, in which the diffusion of atoms between the reflective layer and the protective layer is prevented.

[0042]

According to the method for producing an information recording medium recited in claim 26, in the first reflective layer forming step, assuming that a film thickness of the first reflective layer is d1 (nm), the first reflective layer is formed in a range of 5 nm $\leq$ d1 $\leq$ 15 nm. Thus, a first information layer can be produced, which has high transmittances Tc(%) and Ta(%), diffuses the heat generated in the first recording layer rapidly, and is easily changed into an amorphous state.

[0043]

According to the method for producing an information recording medium recited in claim 27, assuming that a thickness of the first substrate is d2 (μm), 10 μm $\leq$ d2 $\leq$ 700 μm is satisfied. Thus, a first information layer can be produced, in which the length of a recording mark and a region between the recording marks can be optimized in accordance with the groove shape of a first substrate and recording, erasing, and reproducing conditions by changing the NA of an objective lens.

[0044]

According to the method for producing an information recording medium recited in claim 28, the second information layer forming step includes at least a second reflective layer forming step of forming a second reflective layer on the second substrate, a second upper protective layer forming step, a second recording layer forming step, and a second lower protective layer forming step in this order. Thus, a second information layer can be produced, in which recording, erasing, and reproducing can be

performed from the first information layer side.

[0045]

According to the method for producing an information recording medium recited in claim 29, at least one interface layer forming step of a second lower interface layer forming step of forming a second lower interface layer between the second lower protective layer forming step and the second recording layer forming step, a second upper interface layer forming step of forming a second upper interface layer between the second upper protective layer forming step and the second recording layer forming step, and a second interface layer forming step of forming a second interface layer between the second upper protective layer forming step and the second reflective layer forming step is provided. Thus, the diffusion of atoms between the protective layer and the recording layer or between the protective layer and the reflective layer in repeated recording and high-temperature high-humidity recording is prevented, whereby a second information layer having high repetition characteristics and reliability can be produced.

[0046]

According to the method for producing an information recording medium recited in claim 30, assuming that a thickness of the second substrate is d3 (μm), 500 μm ≤ d3 ≤ 1200 μm is satisfied. Thus, a second information layer can be produced, in which the length of a recording mark and a region between the recording marks can be optimized in accordance with the groove shape of a second substrate and recording, erasing, and reproducing conditions by changing the NA of an objective lens.

[0047]

According to the method for recording/reproducing information with

respect to the information recording medium recited in claim 31, a laser beam is incident from a first information layer side, information is recorded/reproduced with respect to a second information layer with the laser beam having passed through the first information layer, and a wavelength λ (nm) of the laser beam is in a range of 390 nm $\leq \lambda \leq$ 430 nm. Thus, both the first information layer and the second information exhibit satisfactory recording and reproducing characteristics in blue violet laser recording.

[0048]

According to the method for recording/reproducing information with respect to an information recording medium recited in claim 32, a linear velocity of the information recording medium in recording/reproducing information is in a range of 1 m/second to 50 m/second. Thus, the length of a recording mark and a region between the recording marks can be optimized in accordance with the groove shape of a first substrate or a second substrate and recording, erasing, and reproducing conditions, whereby a high transfer rate can be obtained.

[0049]

According to the method for recording/reproducing information with respect to an information recording medium recited in claim 33, a numerical aperture NA of an objective lens in recording/reproducing information is 0.4 to 1.1. Thus, the length of a recording mark and a region between the recording marks can be optimized in accordance with the thickness and the groove shape of the first substrate or the second substrate, and recording, erasing, and reproducing conditions.

[0050]

According to the method for recording/reproducing information with

respect to an information recording medium recited in claims 34 to 36, the first information layer records/reproduces information between grooves (groove surface that is closer when seen from a laser beam, also referred to as a groove) or on grooves (groove surface that is placed farther when seen from a laser beam, also referred to as a land), or between grooves and on the grooves. Thus, the length of a recording mark and a region between the recording marks can be optimized in accordance with the thickness and the groove shape of the first substrate, and recording, erasing, and reproducing conditions, whereby high-density recording can be performed.

[0051]

According to the method for recording/reproducing information with respect to an information recording medium recited in claims 37 to 39, the second information layer records/reproduces information between grooves or on grooves, or between grooves and on grooves. Thus, the length of a recording mark and a region between the recording marks can be optimized in accordance with the thickness and the groove shape of the second substrate, and recording, erasing, and reproducing conditions, whereby high-density recording can be performed in both the first and second information layers.

[0052]

[Embodiment of the Invention]

Hereinafter, the present invention will be described by way of embodiments with reference to FIGS. 1 to 4.

[0053]

(Embodiment 1)

FIG. 1 shows one exemplary configuration of an information recording medium 22 of the present invention. A first information layer 11

in which a first lower protective layer 2, a first lower interface layer 3, a first recording layer 4, a first upper interface layer 5, a first upper protective layer 6, a first interface layer 7, a first reflective layer 8, a first uppermost interface layer 9, and a first uppermost protective layer 10 are stacked on a first substrate 1 in this order is attached via an intermediate layer 21 to a second information layer 20 in which a second reflective layer 18, a second interface layer 17, a second upper protective layer 16, a second upper interface layer 15, a second recording layer 14, a second lower interface layer 13, and a second lower protective layer 12 are stacked on a second substrate 19 in this order. A laser beam 23 is incident from the first substrate 1 side. Information is recorded/reproduced with respect to the second information layer 20 with the laser beam 23 having passed through the first information layer 11 and the intermediate layer 21.

[0054]

The first substrate 1 and the second substrate 19 have a transparent disk shape, and as a surface on which films are to be formed, it is possible to use glass or resin such as polycarbonate, amorphous polyolefin, and PMMA on which guide grooves for guiding a laser beam, if required, are formed. The surface on which films are not to be formed, a smooth surface is generally used. Optically, it is preferable that the birefringence in a region of a short wavelength is small. The thickness of the first substrate 1 on the incident side of the laser beam 23 is about 10 μm to 700 μm, and the thickness of the second substrate 19 is about 500 μm to 1300 μm. In particular, polycarbonate is a useful material in terms of an excellent transfer property and productivity, and low cost.

[0055]

The first lower protective layer 2, the first upper protective layer 6,

and the first uppermost protective layer 10 are all made of dielectric thin films, and have a function of regulating an optical distance to enhance a light absorption efficiency to the first recording layer 4, and increasing a change in the amount of reflected light before and after recording to enlarge a signal amplitude. Examples of these protective layers include an oxide such as In_2O_3, SnO, TiO_2, MgO, ZnO, ZrO_2, TeO_2, Al_2O_3, SiO_2, and Ta_2O_5, a nitride such as Si–N, Al–N, Ti–N, Ta–N, Zr–N, and Ge–N, a sulfide such as ZnS, a carbide such as SiC, and a mixture thereof. In order to increase the light absorptivity to the recording film so as to dissipate the heat of the recording film rapidly, it is desirable that a material having a relatively small heat conductivity is used for the first lower protective layer 2 and the first upper protective layer 6, and a material having a relatively large heat conductivity is used for the first uppermost protective layer 10.

[0056]

Furthermore, it is optically preferable that the refractive index in the vicinity of a wavelength of 400 nm is 1.7 or more, and the extinction coefficient is 0.1 or less. Among them, a mixture ZnS–SiO_2 made of an amorphous material is particularly excellent for a protective layer, because it has a high refractive index, a high film formation speed, and satisfactory mechanical characteristics and moisture resistance. The film thickness of the protective layer can be determined strictly so as to satisfy the conditions that the change in the amount of reflected light of the first recording layer 4 crystal phase (before recording) and the first recording layer 4 amorphous phase (after recording) is larger, and the light absorption efficiency to the first recording layer 4 is larger by using calculation based on, for example, a matrix method (see "Wave Optics" by Hiro Kubota, Iwanami-shoten, 1971, Ch. 3)

[0057]

Assuming that the transmittance of the first information layer in the case where the first recording layer is in a crystal phase is Tc(%), and the transmittance of the first information layer in the case where the first recording layer is in an amorphous phase is Ta(%), the first uppermost protective layer 10 has a function of increasing both Tc and Ta, and the transmittance increases from 3% to 5% in terms of an absolute value, compared with the case where the first uppermost protective layer 10 is not formed. The first lower protective layer 2, the first upper protective layer 6, and the first uppermost protective layer 10 may be made of different materials and compositions, if required, and may be made of the same material and composition.

[0058]

The first lower interface layer 3 and the first upper interface layer 5 have a function of preventing the movement of a substance occurring between the first lower protective layer 2 and the first recording layer 4, and between the first upper protective layer 6 and the first recording layer 4 by repeated recording, and are made of a nitride such as Si–N, Al–N, Zr–N, Ti–N, Ge–N, and Ta–N, or a nitride oxide containing these systems, or a carbide such as SiC. In particular, a material containing Ge–N is easily formed by reactive sputtering, and is excellent for an interface layer in terms of mechanical characteristics and moisture resistance. When the film thickness of these interface layers is large, the reflectivity and the absorptivity of a multi-layered configuration change largely to influence recording and erasing performance. Therefore, it is desirable that the film thickness is 1 to 10 nm, more preferably about 3 to 7 nm.

[0059]

The first interface layer 7 and the first uppermost interface layer 9 have a function of preventing the movement of a substance occurring between the first upper protective layer 6 and the first reflective layer 8, and between the first uppermost protective layer 10 and the first reflective layer by high-temperature and high-humidity recording, thereby enhancing reliability, and are made of a nitride such as Si–N, Al–N, Zr–N, Ti–N, Ge–N, and Ta–N, or a nitride oxide containing these systems, or a carbide such as SiC. In particular, a material containing Ge–N is easily formed by reactive sputtering, and is excellent for an interface layer in terms of mechanical characteristics and moisture resistance. When the film thickness of these interface layers is large, the reflectivity and the absorptivity of a multi-layered configuration change largely to influence recording and erasing performance. Therefore, it is desirable that the film thickness is 1 to 10 nm, and more preferably about 3 to 7 nm.

[0060]

The first recording layer 4 of the present invention is made of a phase-change material that is transformed in phase reversibly between a crystal phase and an amorphous phase. Specifically, the first recording layer 4 contains a quarternary composition Ge–Sn–Sb–Te obtained by replacing a part of Ge of a material represented by $Ge_aSb_2Te_{3+a}$ with Sn, and is represented by a composition formula: $(Ge\text{–}Sn)_aSb_bTe_{3+a}$. This material is an excellent material with a high crystallization speed which allows for satisfactory recording and erasing characteristics even with the film thickness of 9 nm or less

[0061]

It is known that a pseudo binary composition $GeTe\text{–}Sb_2Te_3$ is a material with a high crystallization speed, and has been put into practical

use as a material for a recording layer of a phase-change information recording medium. However, when a smaller recording mark is recorded on a recording layer at a shorter distance with a smaller laser beam spot along with the recent increase in capacity, the time during which a laser beam is irradiated to the recording layer becomes relatively short. In order to ensure satisfactory signal quality, the further enhancement of a crystallization speed is required. In order to further enhance the crystallization speed of the pseudo binary composition GeTe–Sb_2Te_3, it is considered to mix a material with a higher crystallization. The inventors of the present invention have found that, as the condition for the above-mentioned material, a material that forms a solid solution with the pseudo binary composition GeTe–Sb_2Te_3 and has the same crystal structure of the rock-salt type as that of the composition. According to an experiment by the inventors, it is found that SnTe, PbTe are in a crystalline state at room temperature, and further have a crystal structure of a rock-salt type, so that they are excellent as a material with a high crystallization speed.

[0062]

They are also highly likely to form a solid solution with Ge–Sb–Te. When the toxicity of Pb is considered, SnTe is a most preferable material. SnTe was mixed in the pseudo binary composition GeTe–Sb_2Te_3, whereby GeTe–SnTe–Sb_2Te_3 was obtained. In this case, by replacing a part of Ge with Sn to form (Ge–Sn)Te–Sb_2Te_3, the crystallization speed becomes large. Furthermore, in the case where excess Sb is added to a system of (Ge–Sn)Te–Sb_2Te_3 to form (Ge–Sn)Te–Sb_2Te_3–Sb, the crystallization speed is increased and the crystallization temperature is enhanced, whereby the thermal stability of a recording mark can be enhanced. Furthermore, Sb also has a function of suppressing the movement of a material caused by

repeated recording, as amorphous Sb, without entering a crystal lattice. When $a < 2$ as the composition range, in a blue violet wavelength region, an optical change is small, and a signal amplitude is insufficient. When $22 < a$ as the composition range, although a signal amplitude becomes large, a melting point increases, and a crystallization speed decreases. Therefore, the range of $2 \leq a \leq 22$ is preferable. $2 \leq a \leq 10$ is a particularly preferable composition excellent in cycle performance. Furthermore, when the concentration of Sn in (Ge–Sn) is too large, the change in a refractive index between a crystal phase and an amorphous phase of the first recording layer becomes small, and recording characteristics decrease.

[0063]

Assuming that the concentration of Ge is x (atomic %), and the concentration of Sn is y (atomic %), $x + y = [100a/(3 + 2a + b)]$ is held, and the preferable range of y is 0 atomic % < y ≤ 11 atomic % when $a = b = 2$, and 0 atomic % < y ≤ 15 atomic % when $a = 2$ and $b = 4$. Furthermore, the preferable range of y is 0 atomic % < y ≤ 22 atomic % when $a = 22$ and $b = 2$, and 0 atomic % < y ≤ 25 atomic % when $a = 22$ and $b = 4$. Thus, it is preferable that y is in a range of 0 atomic % < y ≤ 25 atomic %.

[0064]

FIG. 2 shows a composition range of the recording film of the present invention. This figure is composed of coordinates of the concentration of (Ge–Sn) (atomic %), the concentration of Sb (atomic %), and the concentration of Te (atomic %), and is obtained by connecting points determined by thee concentrations. A point A represents (Ge–Sn)Te at [(Ge–Sn), Sb, Te] (hereinafter, shown in this order) = (50, 0, 50). A point B shows Sb_2Te_3 at (0, 40, 60). Thus, an A–B line shows a(Ge–Sn)Te–Sb_2Te_3 line, i.e., $(Ge–Sn)_aSb_2Te_{3+a}$ line. A point C shows Sb_4Te_3 at (0, 57.1, 42.9).

Thus, an A–C line shows a(Ge–Sn)Te–Sb_4Te_3 line, i.e., $(Ge–Sn)_aSb_4Te_{3+a}$ line.

[0065]

The triangle surrounded by A–B–C is a range of $2 \leq b \leq 4$. A point D is (44.9, 4.1, 52.0) determined by a = 22 and b = 2. A point E is (40, 8, 52) determined by a = 10 and b = 2. A point F is (22.2, 22.2, 55.6) determined by a = 2 and b = 2. A point G is (18.2, 36.4, 45.4) determined by a = 2 and b = 4. A point H is (37, 14.8, 48.2) determined by a = 10 and b = 4. A point J is (43.1, 7.8, 49.1) determined by a = 22 and b = 4. In summary, the composition range of claim 2 is a rectangular range surrounded by D–F–G–J, the composition range of claim 3 is a rectangular range surrounded by E–F–G–H, and the composition range of claim 4 is on a line D–F or E–F.

[0066]

By determining a, b and Sn replacement concentration y by the composition formula: $(Ge–Sn)_aSb_bTe_{3+a}$, in short wavelength (390 nm to 430 nm) recording erasure, the first information layer has satisfactory recording and erasure performance even when the first recording layer has a very small thickness of 6 nm.

[0067]

JP 2–147289 A discloses that an optical information recording member is obtained which has excellent repeated-recording/erasing characteristics and less change in an erasure ratio with time by adding Sb to Te-Ge-Sn as a recording layer so as to fix excess Te as a compound and to limit x, y, z, n of a composition $(Te_xGe_ySn_z)_mSb_n$. However, this is an experimental result in the case where an information recording medium has a different configuration, and the recording layer is thick (i.e., 30 to 100 nm).

This publication does not show the effects of addition of Sn in the case where the recording layer is thinned (6 nm).

[0068]

The composition of the recording layer is represented by $[(Ge{-}Sn)_aSb_bTe_{3+a}]_{100-c}M_c$, and as M, nitrogen, Ag, Al, Cr, Mn, Ti, V, Zr, Nb, Mo, Pd, Cu, Au, Ni, Pt, Zn, In, Ga, Al, Si, Se, Bi, W, Ta, Hf, La, Ce, Nd, Sm, Gd, Tb and Dy can be used. c is 20 atomic % or less. In this case, a crystallization speed can be optimized by varying the concentration of Sn.

[0069]

The first reflective layer 8 optically has a function of increasing the amount of light absorbed by the first recording layer 4, and thermally has a function of enabling heat generated in the first recording layer 4 to radiate rapidly, thereby making it easy for the first recording layer 4 to be changed to an amorphous phase. Furthermore, the first reflective layer 8 also has a function of protecting a multi-layered film from a use environment. As a material for the first reflective layer 8, metal with a high heat conductivity such as Al, Au, Ag, and Cu can be used. Alternatively, it also is possible to use an alloy material, such as Al–Cr, Al–Ti, Au–Pd, Au–Cr, Ag–Pd, Ag–Pd–Cu, Ag–Pd–Ti, and Cu–Si, mainly containing at least one or a plurality of elements among the above metal, to which at least one or a plurality of the other elements is added for the purpose of enhancing moisture resistance or adjusting heat conductivity. These materials are excellent in corrosion resistance and satisfy quenching conditions. In particular, an Ag alloy is an excellent material for the first reflective layer 8 owning to a high heat conductivity and high light transmittance. In order to increase the transmittance Tc, Ta of the first information layer as high as possible, the film thickness of the first reflective layer 8 is preferably 5 nm

to 15 nm, and more preferably 8 nm to 12 nm. Without the first reflective layer 8, the first information layer cannot obtain sufficient reflectivity. Furthermore, in the case where the first reflective layer is provided, when its film thickness is small (i.e., 5 nm), a heat diffusion function is insufficient, and when the film thickness is larger than 15 nm, the transmittance of the first information layer becomes insufficient.

[0070]

The second lower protective layer 12 and the second upper protective layer 16 are both made of dielectric thin films, and have a function of adjusting an optical distance to enhance the light absorptivity to the second recording layer 14, and increasing the change in the amount of reflected light before and after recording to increase a signal amplitude. Regarding these protective layers, the first lower protective layer and the first upper protective layer can be made of a material of the same system, and have the same function. Furthermore, the second lower protective layer 12 and the second upper protective layer 16 may be made of different materials and compositions, if required, and the same material and composition.

[0071]

The second lower interface layer 13 and the second upper interface layer 15 have a function of preventing the movement of a substance occurring between the second lower protective layer 12 and the second recording layer 14, and between the second upper protective layer 16 and the second recording layer 14 by repeated recording, and can be made of a material of the same system as that of the first lower interface layer 3 and the first upper interface layer 5. The more preferable film thickness of the first second lower interface layer 13 and the second upper interface layer 15 is about 3 to 7 nm which is the same as that of the first upper interface

layer 3 and the first upper interface layer 5.

[0072]

The second recording layer 14 has a function of recording, erasing, and reproducing with the laser beam 23 having passed through the first information layer 11, and is made of a material that is transformed in phase reversibly between a crystal phase and an amorphous phase. A system such as Ge–Sb–Te, Ge–Bi–Te, Ge–Sn–Te, In–Sb–Te, Sb–Te, Ge–Te or Ag–In–Sb–Te can be used. Alternatively, a material obtained by adding at least one element selected from the group consisting of Au, Ag, Cu, Al, Ga, Pd, Pt, Ni, Ce, Cr, Bi, Sn, Se, In, La, C, Si, Ti, Mo, W, Ta, Hf, Zr, Nb and V to the above-mentioned system also can be used. It is also possible to add N, O.

[0073]

The second information layer 20 records/erases with the laser beam 23 having passed through the first information layer 11, and the laser beam 23 reflected from the second information layer 20 passes through the first information layer 11 again, whereby a signal can be reproduced. Thus, the first information layer 11 is required to have a high transmittance, and the second information layer 20 has a high reflectivity.

[0074]

The film thickness of the second recording layer 14 is not required to have a high transmittance, so that it is not necessary to set the second recording layer 14 to be very thin. However, when the second recording layer 14 is thick, heat diffuses in an in-plane direction, so that a small recording mark is unlikely to be formed. Furthermore, when the second recording layer 14 is thin, the reflectivity of the second information layer 20 cannot be high, so that the preferably film thickness is 8 nm to 15 nm. As

a material, needless to say, a material of the same Ge–Sn–Sb–Te system as that of the first recording layer 4 of the present invention can be used. However, the film thickness of the second recording layer 14 is larger than that of the first recording layer 4, so that the Sn replacement concentration may be smaller than that of the first recording layer 4. In the composition formula: $(Ge\text{-}Sn)_aSb_bTe_{3+a}$, a is preferably 2 to 10. When a is large, a melting point becomes high, and the second information layer 20 uses transmitted light, so that it is preferable that a melting point is decreased as low as possible so that recording can be performed at a low power. When a = 15, recording sensitivity was poor. Assuming that the concentration of Sn is y (atomic %), for example, in the case where a = 2, 0 atomic % $< y \leq 5$ atomic %, and in the case where a = 10, 0 atomic % $< y \leq 15$ atomic % is preferable. It is preferable that b is $2 \leq b \leq 4$.

[0075]

The second interface layer 17 has a function of preventing the movement of a substance occurring between the second upper protective layer 16 and the second reflective layer 18 by high-temperature and high-humidity recording, thereby enhancing reliability, and can be made of a material of the same system as that of the first interface layer 7. The more preferable film thickness of the second interface layer 17 is about 3 to 7 nm, which is the same as that of the first interface layer 7.

[0076]

The second reflective layer 18 optically has a function of increasing the amount of light absorbed by the second recording layer 14, and thermally has a function of enabling heat generated in the second recording layer 14 to radiate rapidly, thereby making it easy for the second recording layer 14 to be changed to an amorphous phase. Furthermore, the second

reflective layer 18 also has a function of protecting a multi-layered film from a use environment. As a material for the second reflective layer 18, a material of the same system as that of the first reflective layer 8 can be used. The second information layer 20 is not required to have a high transmittance, so that the film thickness of the second reflective layer 18 is preferably in a range of 30 nm to 150 nm, and more preferably in a range of 70 nm to 90 nm. When the second reflective layer 18 has a thickness small than 30 nm, a heat diffusion function is small, and the second recording layer 14 is unlikely to be in an amorphous state. When the second reflective layer 18 has a thickness larger than 150 nm, a heat diffusion function is large, and the recording sensitivity of the second information layer 20 decreases.

[0077]

The intermediate layer 21 is formed for the purpose of distinguishing the focus position of the first information layer 11 from that of the second information layer 20, and in the intermediate layer 21, guide grooves are formed, if required. The intermediate layer 21 can be made of light-curable resin or slow-acting resin. A material for the intermediate layer 21 preferably has no light absorptivity at a wavelength λ of the laser beam for recording/reproducing. The thickness of the intermediate layer 21 is required to be a depth of focus ΔZ or more determined by a numerical aperture NA of an objective lens and the wavelength λ of laser light. In the case where the intensity of a condensing point is 80% of that in the absence of aberration, the depth of focus ΔZ can be approximated by an equation $\Delta Z = \lambda/\{2(NA)^2\}$. Thus, when λ = 400 nm and NA = 0.6, ΔZ = 0.556 μm. In this case, a range within ±0.6 μm falls in the depth of focus, so that the thickness of the intermediate layer 21 should be 1 μm or more. It is

preferable that the upper limit of the thickness of the intermediate layer 21 is prescribed to be a substrate thickness tolerance, allowable by the objective lens, together with the thickness of the first substrate 1, so that the distance between the recording media is in a range in which the objective lens can condense light. Thus, the thickness is preferably 1 μm to 50 μm.

[0078]

(Embodiment 2)

A method for producing an information recording medium 22 of the present invention will be described. First, a first information layer 11 is produced. Guide grooves for guiding a laser beam 23 were formed previously. A first substrate 1 having a thickness of 0.1 mm is attached to a film formation apparatus, and in a first lower protective layer forming step, a first lower protective layer 2 is formed on a guide groove formation side of the first substrate 1. The first lower protective layer 2 can be formed by reactive sputtering in a mixed gas atmosphere of Ar gas and reactive gas, using a metal base material, or by sputtering in an Ar gas atmosphere or in a mixed gas atmosphere of Ar gas and reactive gas, using a chemical base material.

[0079]

Then, in a first lower interface layer forming step, a first lower interface layer 3 is formed on the first lower protective layer 2. The first lower interface layer 3 can be formed by performing reactive sputtering with respect to a metal base material in an Ar gas or reactive gas atmosphere, or by performing sputtering with respect to a chemical base material in an Ar gas atmosphere or in an Ar gas and reactive gas atmosphere.

[0080]

Then, in a first recording layer forming step, a first recording layer 4 is formed on the first lower interface layer 3. The first recording layer 4 can be formed by performing sputtering with respect to a Ge–Sn–Sb–Te alloy base material, using one power source, in an atmosphere of only Ar gas or only krypton (Kr) gas, or in a mixed gas atmosphere of Ar gas and reactive gas (at least one of nitrogen gas and oxygen gas), or in a mixed gas atmosphere of Kr gas and reactive gas.

[0081]

Furthermore, the first recording layer 4 can also be formed by performing sputtering with respect to the respective base materials of Ge, Sn, Sb, Te simultaneously, using four power sources. In this case, an atmosphere of only Ar gas or only Kr gas, or a mixed gas of Ar gas and reactive gas, or a mixed gas of Kr gas and reactive gas is used.

[0082]

Furthermore, the first recording layer 4 can also be formed by performing sputtering with respect to a binary base material or a ternary base material of a combination of any of Ge, Sn, Sb, Te simultaneously, using a plurality of power sources. At this time, the film formation rate of the recording layer is in a range of 0.1 nm/second to 10 nm/second, and a film thickness of 9 nm or less is formed. The film formation rate can be controlled with a power of a power source. When the rate is decreased by decreasing a power, a film formation time increases, and in addition, gas in the atmosphere is mixed in a film more than necessary. Furthermore, when the rate is decreased by decreasing a power, although a film formation time can be shortened, a time cannot be controlled exactly when the film formation time is too short. Thus, it is preferable that the film formation rate of the first recording layer 4 is in a range of 0.1 nm/second to 10

nm/second.

[0083]

According to the production method of the present invention, irrespective of the composition and the shape of a base material, if the composition of a portion of the formed first recording layer 4 excluding a reactive gas component is $(Ge-Sn)_aSb_bTe_{3+a}$, an excellent information recording medium 22 can be produced.

[0084]

Then, in a first upper interface layer forming step, a first upper interface layer 5 is formed on the first recording layer 4. The first upper interface layer 5 can be formed by the same production method as that of the first lower interface layer 3. In both the interface layer forming steps, a base material may be the same or different.

[0085]

Then, in the first upper protective layer forming step, a first upper protective layer 6 is formed on the first upper interface layer 5. The first upper protective layer 6 can be formed by the same production method as that of the first lower protective layer 2. In both the protective layer forming steps, a base material may be the same or different.

[0086]

Then, in a first interface layer forming step, a first interface layer 7 is formed on the first upper protective layer 6. The first interface layer 7 can be formed by the same production method as that of the first lower interface layer 3 or the first upper interface layer 5. In these interface layer forming steps, a base material may be the same or different.

[0087]

Then, in a first reflective layer forming step, a first reflective layer 8

is formed on the first interface layer 7. The first reflective layer 8 can be formed by performing sputtering with respect to a metal base material in an Ar gas atmosphere.

[0088]

Then, in a first uppermost interface layer forming step, a first uppermost interface layer 9 is formed on the first reflective layer 8. The first uppermost interface layer 9 can be formed by the same production method as that of the first lower interface layer 3 or the first upper interface layer 5 or the first interface layer 7. In these interface layer forming steps, a base material may be the same or different.

[0089]

Then, in a first uppermost protective layer forming step, a first uppermost protective layer 10 is formed on the first uppermost interface layer 9. The first uppermost protective layer 10 can be formed by the same production method as that of the first lower protective layer 2 or the first upper protective layer 6. In these protective layer forming steps, a base material may be the same or different. After the layers from the first lower protective layer 2 to the first uppermost protective layer 10 were formed, if required, an initialization step in which the first recording layer 4 was crystallized over the entire surface was performed, whereby the production of the first information layer was completed.

[0090]

Next, the second information layer 20 is produced. A second substrate 19 having a thickness of 1.1 mm in which guide grooves for guiding a laser beam 23 are formed previously is attached to a film formation apparatus, and in a second reflective layer forming step, a second reflective layer 18 is formed on a guide groove formation side of the second

substrate 19. The second reflective layer 18 can be formed by performing sputtering with respect to a metal base material in an Ar gas atmosphere.

[0091]

Then, in a second interface layer forming step, a second interface layer 17 is formed on the second reflective layer 18. The second interface layer 17 can be formed by performing reactive sputtering with respect to a metal base material in an Ar gas or reactive gas atmosphere, or by performing sputtering with respect to a chemical base material in an Ar gas atmosphere or in an Ar gas and reactive gas atmosphere.

[0092]

Then, in a second upper protective layer forming step, a second upper protective layer 16 is formed on the second interface layer 17. The second upper protective layer 16 can be formed by performing reactive sputtering with respect to a metal base material in a mixed gas atmosphere of Ar gas and reactive gas, or by performing sputtering with respect to a chemical base material in an Ar gas atmosphere or in a mixed gas atmosphere of Ar gas and reactive gas.

[0093]

Then, in a second upper interface layer forming step, a second upper interface layer 15 is formed on the second upper protective layer 16. The second upper interface layer 15 can be formed by the same production method as that of the second interface layer 17. In both the interface layer forming steps, a base material may be the same or different.

[0094]

Then, in a second recording layer forming step, a second recording layer 4 is formed on the second upper interface layer 15. The second recording layer 14 can be formed by performing sputtering with respect to,

for example, a Ge–Sb–Te alloy base material in an atmosphere of only Ar gas or only krypton (Kr) gas, or in a mixed gas atmosphere of Ar gas and reactive gas (at least one of nitrogen gas and oxygen gas), or in a mixed gas atmosphere of Kr gas and reactive gas.

[0095]

Then, in a second lower interface layer forming step, a second lower interface layer 13 is formed on the second recording layer 14. The second lower interface layer 13 can be formed by the same production method as that of the second interface layer 17 or the second upper interface layer 15. In these interface layer forming steps, a base material may be the same or different.

[0096]

Then, in a second lower protective layer forming step, a second lower protective layer 12 is formed on the second lower interface layer 13. The second lower protective layer 12 can be formed by the same production method as that of the second upper protective layer 16. In both the protective layer forming steps, a base material may be the same or different.

[0097]

After the layers from the second reflective layer 18 to the second lower protective layer 12 were formed, if required, an initialization step in which the second recording layer 14 was crystallized over the entire surface was performed, whereby the production of the second information layer was completed.

[0098]

Finally, an information recording medium 22 is produced. An intermediate layer 21 is formed on the second lower protective layer 12 of the second information layer 20 by spin coating, and the first information

layer 11 is brought into contact therewith. The intermediate layer 21 was cured by irradiating UV-rays from the first substrate side, whereby the production of the information recording medium 22 was completed.

[0099]

(Embodiment 3)

A method for producing the information recording medium 40 of the present invention will be described with reference to FIG. 3. First, a second information layer 20 is produced. A second substrate 19 having a thickness of 1.1 mm in which guide grooves for guiding a laser beam 23 are formed previously is attached to a film formation apparatus, and in a second reflective layer forming step, a second reflective layer 18 is formed on a guide groove formation side of the second substrate 19. Then, in a second interface layer forming step, a second interface layer 17 is formed on the second reflective layer 18. Then, in a second upper protective layer forming step, a second upper protective layer 16 is formed on the second interface layer 17. Then, in a second upper interface layer forming step, a second upper interface layer 15 is formed on the second upper protective layer 16. Then, in a second recording layer forming step, a second recording layer 14 is formed on the second upper interface layer 15. Then, in a second lower interface layer forming step, a second lower interface layer 13 is formed on the second recording layer. Then, in a second lower protective layer forming step, a second lower protective layer 12 is formed on the second lower interface layer 13.

[0100]

After the layers from the second reflective layer 18 to the second lower protective layer 12 were formed, if required, an initialization step in which the second recording layer 14 was crystallized over the entire surface

was performed, whereby the production of the second information layer 20 was completed.

[0101]

Next, a first information layer 42 is produced on the second information layer 20. An intermediate layer 21 is formed. An intermediate layer 21 is formed on the second lower protective layer 12 by spin coating. A guide groove side of a polycarbonate substrate on which guide grooves are previously formed is brought into contact with the intermediate layer 21, and the intermediate layer 21 is irradiated with UV-rays to be cured. The polycarbonate substrate on which the guide grooves are formed is peeled, whereby guide grooves are formed on the intermediate layer 21. Next, the substrate in which the intermediate layer 21 is formed on the second information layer 20 is attached to a film formation apparatus, and in a first uppermost protective layer forming step, a first uppermost protective layer 10 is formed on the intermediate layer 21.

[0102]

Then, in a first uppermost interface layer forming step, a first uppermost interface layer 9 is formed on the first uppermost protective layer 10. Then, in a first reflective layer forming step, a first reflective layer 8 is formed on the first uppermost interface layer 9. Then, in a first interface layer forming step, a first interface layer 7 is formed on the first reflective layer 8. Then, in a first upper protective layer forming step, a first upper protective layer 6 is formed on the first interface layer 7. Then, in a first upper interface layer forming step, a first upper interface layer 5 is formed on the first upper protective layer 6. Then, in a first recording layer forming step, a first recording layer 4 is formed on the first upper interface layer 5. Then, in a first lower interface layer forming step, a first lower

interface layer 3 is formed on the first recording layer 4. Then, in a first lower protective layer forming step, a first lower protective layer 2 is formed on the first lower interface layer 3.

[0103]

After the layers from the first uppermost protective layer 10 to the first lower protective layer 2 were formed, if required, an initialization step in which the first recording layer 4 was crystallized over the entire surface was performed. Then, an adhesive layer 41 is formed on the first lower protective layer 2 by spin coating, and a first substrate 1 having a thickness of 0.1 mm is brought into contact with the adhesive layer 41. The adhesive layer 41 is cured by irradiation with UV-rays. Thus, the first information layer 42 was produced, and the production of the information recording medium 40 was completed. As the material for the adhesive layer 41, light-curable resin or slow-acting resin can be used in the same way as in the intermediate layer 21. The thickness is preferably 5 μm to 40 μm.

[0104]

(Embodiment 4)

A recording/reproducing method of the information recording medium 22 of the present invention will be described. As shown in FIG. 4, recording/erasing/reproducing performance of the information recording medium 22 was evaluated, using a system including a spindle motor 27 for rotating the information recording medium 22, an optical head 26 with a semiconductor laser 25, and an objective lens 24 for condensing a laser beam 23 onto the first recording layer 4 or the second recording layer 14 of the information recording medium 22. Information is recorded by modulating the laser beam 23 to a higher peak power (Pp(mW)) and a lower bias power (Pb(mW)). An amorphous phase is formed by Pp(mW), which becomes a

recording mark. Between recording marks, a crystal phase is formed by Pb(mW).

[0105]

When the first information layer 11 is recorded/reproduced, the laser beam 23 is directly incident upon the first recording layer 4 to record information on the first recording layer 4. Reproduction is performed with the laser beam 23 reflected from the first recording layer 4. When the second information layer 20 is recorded/reproduced, information is recorded on the second recording layer 14 with the laser beam 23 transmitted through the first information layer 11 and the intermediate layer 21. Reproduction is performed with the laser beam 23 reflected from the second recording layer 14, and transmitted through the intermediate layer 21 and the first information layer 11.

[0106]

As dynamic evaluation, regarding recording performance, a 3T signal was recorded 10 times to measure an amplitude vs. noise ratio (CNR). Regarding erasing performance, a 3T signal was recorded 10 times to measure an amplitude, and a 11T signal was overwritten thereon once, and an attenuation ratio of a 3T amplitude was measured as an erasure ratio.

[0107]

(Embodiment 5)

A system for performing static evaluation of a Ge–Sn–Sb–Te recording film of the present invention will be described. First, a thin film sample 28 as shown in FIG. 3 was prepared. A first lower protective layer 2 to a first reflective layer 8 were formed on a substrate 34 in a first information layer forming step, and attached to a dummy substrate 35 with an adhesive layer 36. The first recording layer 4 may remain an

amorphous phase (as–depo amorphous phase) after forming, without performing initialization. The thin film sample 28 had substantially the same configuration as that of the first information layer 11 so that the static characteristics of the present embodiment can be compared with the dynamic characteristics of Embodiment 4. As the substrate 34 and the dummy substrate 35, any transparent material such as glass, polycarbonate, or amorphous polyolefin can be used. It is desirable that the thin film sample 28 has smallest possible warpage and distortion, and it is preferable that the substrate 34 and the dummy substrate 35 are made of the same material and have the same shape. As the adhesive layer 36, light-curable resin or slow-acting resin can be used.

[0108]

As shown in FIG. 6, the thin film sample 28 was placed on a thin film sample fixing stage 29, and the crystallization time of the thin film sample 28 was measured using a system including an optical head 33 with a semiconductor laser 32, and an objective lens 31 for condensing a laser beam 30 onto the first recording layer 4 of the thin film sample 28. The semiconductor laser 32 with a wavelength of 405 nm and the objective lens 31 with a NA of 0.65 were used. Measurement was performed by irradiating the laser beam 30 to the thin film sample 28 three times. Measurement was performed by fixing the power (mW) of the pulse 3, with a lower and longer power for changing the first recording layer 4 from an as–depo amorphous phase to a crystal phase in first irradiation (pulse 1), a higher and shorter power for once melting a crystal phase to change it to an amorphous phase in second irradiation (pulse 2), and a lower and longer power for changing from an amorphous phase to a crystal phase in third irradiation (pulse 3), and changing an irradiation time (ns). The change in

a crystal phase ⇔ amorphous phase is determined from the change in reflectivity of the thin film sample 28 at a time of irradiation of the laser beam 30. It can be determined that a short crystallization time is equal to a high crystallization speed.

[0109]

[Examples]

Next, specific examples of the present invention will be described.

[0110]

(Example 1)

In the present example, the thin film sample 28 in FIG. 5 was prototyped, and the crystallization time of the first recording layer 4 of the present invention was measured using the static evaluation system in FIG. 6. As the substrate 34, a polycarbonate substrate of 12 mm × 18 mm × 0.6 mm (thickness) was prepared. On the substrate 34, ZnS−20 mol% SiO2 was formed to 90 nm as the first lower protective layer 2, Ge−N was formed to 3 nm as the first lower interface layer 3, $(Ge-Sn)_4Sb_2Te_7$ (a = 4, b = 2, x + y = 30.8 atomic%, y = 0, 5, 10, 15, 20 atomic%) was formed to 3 nm to 12 nm as the first recording layer 4, Ge−N was formed to 3 nm as the first upper interface layer 5, ZnS−20 mol% SiO2 was formed to 36 nm as the first upper protective layer 6, Ge−N was formed to 3 nm as the first interface layer 7, and an Ag alloy was formed to 10 nm as the first reflective layer 8 successively by sputtering in the first information layer forming step. UV-curable resin was applied to the first reflective layer 8 as the adhesive layer 36, and the dummy substrate 35 was brought into contact with the resultant stack so that the dummy substrate 35 is not shifted, and attached thereto by irradiation of UV-rays.

[0111]

Herein, the film thicknesses of the first lower protective layer 2 and the first upper protective layer 6 were strictly determined so as to satisfy the condition that the reflectivity change of the first recording layer 4 at a wavelength of 405 nm became larger, and the light absorptivity to the first recording layer 4 became larger by calculation based on a matrix method.

[0112]

The film formation conditions in the first information layer forming step were as follows. The first lower protective layer 2 and the first upper protective layer 6 were formed by performing high-frequency sputtering of 400 W with respect to a ZnS−20 mol% SiO_2 compound base material (thickness: ϕ100 mm × 6 mm thickness) in an Ar gas atmosphere. The first lower interface layer 3 and the first upper interface layer 5 and the first interface layer 7 were formed by performing high-frequency sputtering of 300 W with respect to a Ge metal base material (thickness: ϕ100 mm × 6 mm) in a mixed gas atmosphere of Ar gas and nitrogen gas. The first recording layer 4 was formed by performing DC sputtering of 50 W with respect to a GeSnSbTe alloy base material (thickness: ϕ100 mm × 6 mm), using one power source. The film formation rate of the first recording layer 4 in the present example was 0.5 nm/second, and the film thickness of 3 nm to 12 nm was formed in 6 to 24 seconds. The first reflective layer 8 was formed by performing DC sputtering of 200 W with respect to an Ag alloy base material (thickness: ϕ100 mm × 6 mm) in an Ar gas atmosphere.

[0113]

In the system shown in FIG. 6, the pulse 1 was 500 ns at 3.5 mW, the pulse 2 was 40 ns at 7 mW, and the pulse 3 was varied from 10 ns to 500 ns at 3 mW, and the time at which a reflectivity change occurred was set to be a crystallization time. Table 1 shows the results.

[0114]

[Table 1]

x (atomic %)	y (atomic %)	Thin film sample 28 No.	Film thickness (nm)	Crystallization time (ns)
30.8	0	1-1	3	>500
		1-2	4	500
		1-3	5	200
		1-4	6	90
		1-5	7	65
		1-6	8	50
		1-7	9	40
		1-8	10	30
		1-9	11	30
		1-10	12	30
25.8	5	1-11	3	>500
		1-12	4	400
		1-13	5	150
		1-14	6	70
		1-15	7	50
		1-16	8	30
		1-17	9	30
		1-18	10	30
		1-19	11	30
		1-20	12	30
20.8	10	1-21	3	400
		1-22	4	200
		1-23	5	80
		1-24	6	50
		1-25	7	40
		1-26	8	30
		1-27	9	20
		1-28	10	20
		1-29	11	20
		1-30	12	20
15.8	15	1-31	3	300
		1-32	4	100
		1-33	5	60
		1-34	6	20
		1-35	7	20
		1-36	8	20
		1-37	9	20
		1-38	10	20
		1-39	11	20
		1-40	12	20
10.8	20	1-41	3	200
		1-42	4	60
		1-43	5	30
		1-44	6	15
		1-45	7	15
		1-46	8	15
		1-47	9	15
		1-48	10	15
		1-49	11	15
		1-50	12	15

[0115]

From the above results, the following is understood: as the concentration of Sn increases, the crystallization time becomes shorter, and as the film thickness decreases, the tendency thereof becomes larger. It was verified using static evaluation means that the crystallization time is shortened by adding Sn to Ge–Sb–Te.

[0116]

(Example 2)

In the present example, the transmittance of the first information layer 11 in FIG. 11 was measured. As a procedure, a sample for measurement of the first information layer 11 was produced, first, the transmittance (Ta) of an amorphous phase of the first recording layer 4 was measured, the first recording layer 4 was initialized after measurement to be crystallized, and the transmittance (Tc) of a crystal phase was measured. The measurement was conducted by reading the value at a wavelength of 405 nm, using a spectroscope. After measurement, (Tc + Ta)/2 was calculated, and it was determined to which degree the first recording layer 4 should be made thin.

[0117]

As the substrate 1, a polycarbonate substrate of ϕ120 mm × 0.1 mm (thickness) was prepared. On the substrate 1, ZnS–20 mol% SiO_2 was formed as the first lower protective layer 2, Ge–N was formed to 3 nm as the first lower interface layer 3, $(Ge\text{–}Sn)_4Sb_2Te_7$ (a = 4, b = 2, x + y = 30.8 atomic%, y = 10%) was formed to 3 nm to 12 nm as the first recording layer 4, Ge–N was formed to 3 nm as the first upper interface layer 5, ZnS–20 mol% SiO2 was formed as the first upper protective layer 6, Ge–N was formed to 3 nm as the first interface layer 7, an Ag alloy was formed to 10

nm as the first reflective layer 8, Ge–N was formed to 3 nm as the first uppermost interface layer 9, and ZnS–20 mol% SiO2 was formed as the first uppermost protective layer 10 successively by sputtering in the first information layer forming step.

[0118]

Herein, the film thicknesses of the first lower protective layer 2 and the first upper protective layer 6 were strictly determined with respect to each film thickness of the first recording layer 4 so as to satisfy the condition that the reflectivity change of the first recording layer 4 at a wavelength of 405 nm became larger, and the light absorptivity to the first recording layer 4 became larger by calculation based on a matrix method. Furthermore, the film thickness of the first uppermost protective layer 10 was determined strictly so that the transmittance became higher without impairing the reflectivity change and the light absorptivity of the first information layer 11.

[0119]

The intermediate layer 21 was formed on the second substrate 19 by spin coating, the first information layer 11 that has already been formed was brought into contact with the intermediate layer 21, and the intermediate layer 21 was cured by irradiation of UV-rays. Thus, a sample for measuring a transmittance was produced. Table 2 shows transmittance measurement results.

[0120]

[Table 2]

x (atomic %)	y (atomic %)	Sample for transmittance No.	Film thickness (nm)	Ta (%)	Tc (%)	(Tc+Ta)/2 (%)
20.8	10	2-1	3	58	64	61
		2-2	4	54	60	57
		2-3	5	50	56	53
		2-4	6	47	53	50
		2-5	7	44	50	47
		2-6	8	40	46	43
		2-7	9	37	43	40
		2-8	10	34	40	37
		2-9	11	31	37	34
		2-10	12	27	33	30

[0121]

From the above results, the following was understood: if the first recording layer 4 is 9 nm or less, the first information layer 11 obtains 40% $\leq$ (Tc + Ta)/2, and if the first recording layer 4 is 6 nm or less, the first information layer 11 obtains 50% $\leq$ (Tc + Ta)/2. Thus, it is preferable that the film thickness of the first recording layer 4 is 9 nm or less.

[0122]

(Example 3)

In the present example, the information recording medium 22 in FIG. 1 was produced, and the erasure ratio and CNR of the first information layer 11 of the present invention were measured using the dynamic evaluation system in FIG. 4. As the substrate 1, a polycarbonate substrate of ϕ120 mm $\times$ 0.1 mm (thickness) was prepared. On the substrate 1, ZnS–20 mol% SiO_2 was formed as the first lower protective layer 2, Ge–N was formed to 3 nm as the first lower interface layer 3, $(Ge\text{–}Sn)_4Sb_2Te_7$ (a = 4, b = 2, x + y = 30.8 atomic%, y = 0, 5, 10, 15, 20 atomic%) was formed to 3 nm to 9 nm as the first recording layer 4, Ge–N was formed to 3 nm as the

first upper interface layer 5, ZnS–20 mol% SiO_2 was formed as the first upper protective layer 6, Ge–N was formed to 3 nm as the first interface layer 7, an Ag alloy was formed to 10 nm as the first reflective layer 8, GeN was formed to 3 nm as the first uppermost interface layer 9, and ZnS–20 mol% SiO_2 was formed as the first uppermost protective layer 10 successively by sputtering in the first information layer forming step.

[0123]

Next, as the second substrate 19, a polycarbonate substrate of ϕ120 mm × 1.1 mm (thickness) was prepared. On the substrate 19, an Ag alloy was formed to 80 nm as the second reflective layer 18, Ge–N was formed to 3 nm as the second interface layer 17, ZnS–20 mol% SiO_2 was formed as the second upper protective layer 16, Ge–N was formed to 3 nm as the second upper interface layer 15, $Ge_4Sb_2Te_7$ was formed to 12 nm as the second recording layer 14, Ge–N was formed to 3 nm as the second lower interface layer 13, and ZnS–20 mol% SiO_2 was formed as the second lower protective layer 12 successively by sputtering in the second information layer forming step.

[0124]

Herein, even regarding the second information layer 20, the film thicknesses of the second lower protective layer 12 and the second upper protective layer 16 were strictly determined so as to satisfy the condition that the reflectivity change of the second recording layer 14 at a wavelength of 405 nm became larger, and the light absorptivity to the second recording layer 14 became larger by calculation based on a matrix method.

[0125]

The first information layer 11 and the second information layer 20 were initialized, UV-curable resin was formed on the intermediate layer 21

onto the second lower protective layer by spin coating, the first information layer 11 was brought into contact with the intermediate layer 21, and the intermediate layer was cured by irradiation of UV-rays from the first substrate 1 side, whereby the information recording medium 22 was produced. Similarly, the information recording media 22 in which the composition and film thickness of the first recording layer 4 were varied were produced respectively.

[0126]

The erasure ratio of each information recording medium 22 was measured using the dynamic evaluation system in FIG. 4. As a recording condition, the semiconductor laser 25 with a wavelength of 405 nm was used, and the objective lens 24 with an NA of 0.85 was used. Furthermore, the linear velocity of the information recording medium 22 at a time of measuring an erasure ratio・CNR is 8.6 m/s. This is recording on grooves. (Table 3) shows the results. × represents an erasure ratio < 20 dB or CNR < 40 dB, △ represents 20 dB ≤ erasure ratio < 40 dB or 40 dB ≤ CNR < 50 dB, and ○ represents 30 dB ≤ erasure ratio and 50 dB ≤ CNR.

[0127]

[Table 3]

x (atomic %)	y (atomic %)	Information recording medium 22 No.	Film thickness (nm)	Erasure ratio (dB)	CNR (dB)	Determi nation
30.8	0	3-1	3	0	20	×
		3-2	4	0	30	×
		3-3	5	5	37	×
		3-4	6	10	44	×
		3-5	7	15	46	×
		3-6	8	20	46	△
		3-7	9	25	46	△
25.8	5	3-8	3	0	25	×
		3-9	4	5	35	×
		3-10	5	10	40	×
		3-11	6	15	46	×
		3-12	7	20	50	△
		3-13	8	25	50	△
		3-14	9	30	50	○
20.8	10	3-15	3	20	40	△
		3-16	4	25	47	△
		3-17	5	30	52	○
		3-18	6	34	52	○
		3-19	7	34	52	○
		3-20	8	35	52	○
		3-21	9	35	52	○
15.8	15	3-22	3	23	43	△
		3-23	4	25	48	△
		3-24	5	30	52	○
		3-25	6	36	52	○
		3-26	7	36	52	○
		3-27	8	36	52	○
		3-28	9	36	52	○
10.8	20	3-29	3	25	37	×
		3-30	4	30	43	△
		3-31	5	35	48	△
		3-32	6	38	45	△
		3-33	7	38	45	△
		3-34	8	38	45	△
		3-35	9	38	45	△

[0128]

From the above results, in the information recording media 22 of Nos. 3−1 to 3−7, in which Sn was not added, the erasure ratio and the CNR were both low. Particularly, in a medium with a film thickness of 6 nm, the

erasure ratio was 10 dB or less. When Sn was added, the erasure ratio increased, and in the medium of No. 3–18 with 10% Sn, satisfactory results: erasure ratio of 34 db and CNR of 52 dB at 6 nm were obtained. It was verified that the erasure ratio was remarkably enhanced by adding Sn. However, in the media of Nos. 3–29 to 3–35 with 20% Sn, although the erasure ratio was high, the CNR decreased. This is considered from the static evaluation results of Example 1 that a crystallization time was too short, and a recording mark was not formed to a satisfactory size when information was recorded. In other words, a crystal phase is very likely to be formed, and an amorphous phase is unlikely to be formed. The above is also considered to be caused by the decrease in a refractive index between a crystal phase and an amorphous phase. From the results of the present example, in the Ge concentration x (atomic %) and the Sn concentration y (atomic %), satisfactory recording/erasing characteristics were obtained about up to $x = y$, and the CNR decreased at $x < y$. Particularly, in a range of $x/2 \leq y \leq x$, outstanding characteristics were exhibited in both the erasure ratio and the CNR.

[0129]

(Example 4)

In the present example, assuming that $b = 2$ and y = about $x/2$, the relationship between the value of a and the crystallization time was checked. The experiment was conducted using the first recording layer 4 of 9 kinds of compositions of $(Ge\text{–}Sn)_aSb_2Te_{3+a}$ (a = 1, 2, 4, 6, 8, 10, 14, 22, 44) with a thickness of 6 nm. The thin film sample 28 in FIG. 5 was prototyped under the same condition as that of Example 1 except for the composition and film thickness of the first recording layer 4, and a static evaluation system in FIG. 6 was used. Table 4 shows the results.

[0130]

[Table 4]

a	x+y (atomic %)	y (atomic %)	Thin film sample 28 No.	Crystallization time (ns)
1	14.3	5	4-1	10
2	22.2	7	4-2	30
4	30.8	10	4-3	50
6	35.3	12	4-4	60
8	38.1	13	4-5	70
10	40.0	13	4-6	80
14	42.4	14	4-7	90
22	44.9	15	4-8	100
44	47.3	16	4-9	110

[0131]

From the above results, the following was found: when the value of a increases, the crystallization time becomes relatively longer.

[0132]

(Example 5)

In the present example, assuming that b = 2 and y = about x/2, the relationship among the value of a, the CNR, and the erasure ratio was checked. The experiment was conducted using the first recording layer 4 of 9 kinds of compositions of $(Ge{-}Sn)_aSb_2Te_{3+a}$ (a = 1, 2, 4, 6, 8, 10, 14, 22, 44) with a thickness of 6 nm. The information recording medium 22 in FIG. 1 was produced under the same condition as that of Example 3 except for the composition and film thickness of the first recording layer 4, and a static evaluation system in FIG. 4 was used. (Table 5) shows the results. × represents an erasure ratio < 20 dB or CNR < 40 dB, △ represents 20 dB ≤ erasure ratio < 40 dB or 40 dB ≤ CNR < 50 dB, and ○ represents 30 dB ≤ erasure ratio and 50 dB ≤ CNR.

[0133]

[Table 5]

a	x+y (atomic %)	y (atomic %)	Information Recording medium 22 No.	Erasure ratio (dB)	CNR (dB)	Determination
1	14.3	5	5-1	30	35	×
2	22.2	7	5-2	34	40	△
4	30.8	10	3-18	34	52	○
6	35.3	12	5-4	32	53	○
8	38.1	13	5-5	30	54	○
10	40.0	13	5-6	22	55	△
14	42.4	14	5-7	16	55	×
22	44.9	15	5-8	14	56	×
44	47.3	16	5-9	10	57	×

[0134]

From the above results, the following was found: when the value of a is small, the CNR is low, and when the value of a is large, the erasure ratio decreases. This tendency is well matched with the a-value dependence of the crystallization time of Example 4. In the case where b = 2 and y = about x/2, as the range of a where both the erasure ratio · CNR are satisfactory, $2 \leq a \leq 10$ is preferable.

[0135]

(Example 6)

In the present example, assuming that b = 2 and y = about x, the relationship among the value of a, the CNR, and the erasure ratio was checked. The experiment was conducted using the first recording layer 4 of 9 kinds of compositions of $(Ge\text{–}Sn)_aSb_2Te_{3+a}$ (a = 1, 2, 4, 6, 8, 10, 14, 22, 44) with a thickness of 6 nm. The information recording medium 22 in FIG. 1 was produced under the same condition as that of Example 3 except for the composition and film thickness of the first recording layer 4, and a static evaluation system in FIG. 4 was used. (Table 6) shows the results. × represents an erasure ratio < 20 dB or CNR < 40 dB, △ represents 20 dB ≤

erasure ratio < 40 dB or 40 dB ≤ CNR < 50 dB, and ○ represents 30 dB ≤ erasure ratio and 50 dB ≤ CNR.

[0136]

[Table 6]

a	x+y (atomic %)	y (atomic %)	Information Recording medium 22 No.	Erasure ratio (dB)	CNR (dB)	Determination
1	14.3	7	6-1	30	37	×
2	22.2	11	6-2	34	42	△
4	30.8	15	3-25	36	52	○
6	35.3	17	6-4	36	53	○
8	38.1	19	6-5	34	54	○
10	40.0	20	6-6	30	54	○
14	42.4	21	6-7	26	54	△
22	44.9	22	6-8	20	53	△
44	47.3	23	6-9	16	53	×

[0137]

From the above results, the following is understood: in the case where b = 2 and y = about x, as the range of a where both the erasure ratio · CNR are satisfactory, 2 ≤ a ≤ 22 is preferable.

[0138]

(Example 7)

In the same way as in Example 3, the information recording medium 22 in FIG. 1 was produced, and the recording cycle performance and the recording storage property of the first information layer 11 of the present invention were evaluated, using the dynamic evaluation system in Fig. 4. As to the cycle performance, the number of times at which the amplitude of 3T decreases by 3dBm was set to be life. A 3T amplitude was measured by repeatedly recording a 3T signal and a random signal. The recording storage property was measured by recording a 3T signal onto a recording medium, leaving the recording medium in an atmosphere of 90°C and a relative humidity of 20% for 100 hours, and thereafter, determining how

much the amplitude of the 3T signal decreases. It is understood that the thermal stability of a recording mark is degraded more, as the decrease is larger.

[0139]

In the present example, the values of b and y were changed. The experiment was conducted with a $(Ge-Sn)_{22}Sb_bTe_{25}$ composition and a film thickness of 6 nm. (Table 7) shows the results. × represents a cycle life number of times < 1000, 3dB ≤ 3T amplitude decrease; △ represents 1000 ≤ cycle life number of times < 5000, 1 ≤ 3T amplitude decrease < 3dB; ○ represents 5000 ≤ cycle life number of times < 10000, 0 < 3T amplitude decrease < 1dB; ◎ represents 10000 ≤ cycle number of times, 3T amplitude decrease = 0; and – represents that a crystallization speed is low, and an erasure ratio < 10 dB.

[0140]

[Table 7]

y (atomic %)	b	Information recording medium 22 No.	Cycle performance	Recording storage property
10	2	7-1	△	○
	2.5	7-2	○	◎
	3	7-3	○	◎
	3.5	7-4	×	–
	4	7-5	×	–
	4.5	7-6	×	–
	5	7-7	×	–
15	2	7-8	△	○
	2.5	7-9	○	○
	3	7-10	○	◎
	3.5	7-11	◎	◎
	4	7-12	×	–
	4.5	7-13	×	–
	5	7-14	×	–
20	2	7-15	△	△
	2.5	7-16	○	○
	3	7-17	○	○
	3.5	7-18	◎	◎
	4	7-19	◎	◎
	4.5	7-20	×	–
	5	7-21	×	–
25	2	7-22	△	△
	2.5	7-23	○	△
	3	7-24	○	○
	3.5	7-25	◎	◎
	4	7-26	◎	◎
	4.5	7-27	×	–
	5	7-28	×	–
30	2	7-29	×	×
	2.5	7-30	×	×
	3	7-31	×	×
	3.5	7-32	×	×
	4	7-33	×	×
	4.5	7-34	×	×
	5	7-35	×	×

[0141]

As a result, in the case where the concentration of Sn is constant, cycle performance is enhanced more when Sb is increased. Furthermore, it is understood that, by increasing both Sb and Sn concentration, a composition range satisfying the cycle performance and the recording storage property is enlarged. When y = 30 atomic %, a crystallization speed was too high to form a recording mark. When $4.5 \leq b$, a crystallization speed was low, so that erasure was not performed. Thus, when $a = 22$, $2 \leq b \leq 4$, $0 < y \leq 2.5$ atomic % are preferable.

[0142]

(Example 8)

When the experiment of Example 7 was conducted at $a = 2$. $0 < y \leq 15$ atomic % was a preferable range at $2 \leq b \leq 4$.

[0143]

(Example 9)

In the present example, a preferable film thickness of a reflective layer is determined. The sample for measuring a transmittance produced in Example 2 was also produced in the present example. As the first recording layer 4, a $(Ge\text{-}Sn)_4Sb_2Te_7$ composition with a film thickness being varied from 1 nm to 9 nm was used. As the first reflective layer 8, a sample with a different film thickness of an Ag alloy was produced. The film thickness is 3, 5, 7, 10, 12, 15, 17, and 20 nm. The reflectivity, transmittance, and 3T amplitude were measured.

[0144]

As a result, it was found that the film thickness of the first reflective layer is preferably 5 nm to 15 nm, and more preferably 8 nm to 12 nm. Without the first reflective layer 8, the first information layer did not obtain

sufficient reflectivity. Furthermore, in the case of providing the first reflective layer, when the thickness thereof was less than 5 nm, a heat diffusion function was insufficient, and a 3T amplitude was small. Furthermore, when the thickness was larger than 15 nm, the transmittance of the first information layer became insufficient.

[0145]

(Example 10)

In the same way as in Example 3, the information recording medium 22 in FIG. 1 was produced, and the erasure ratio and the CNR of the first information layer 11 and the second information layer 20 of the information recording medium 22 of the present invention were measured, using the dynamic evaluation system in FIG. 4. In the present example, the first recording layer 4 had a composition of $(Ge{-}Sn)_4Sb_2Te_7$, y = 10 atomic % and a film thickness of 6 nm. Furthermore, evaluation was made by varying the recording groove surface of the first information layer 11 and the second information layer 20. A region between grooves refers to a closer groove surface when seen from a laser beam, and a region on the grooves refers to a farther groove surface when seen from the laser beam. The other production conditions, and the recording and erasing conditions are the same as those in Example 3. The transmittance of the first information layer 11 was 50% as an average value. (Table 8) shows the measurement results of an erasure ratio and a CNR.

[0146]

[Table 8]

Information recording medium 22 No.: 3−18

First information layer 11				Second information layer 20			
Recording groove	CNR (dB)	Erasure ratio (dB)	Recording power Pp/Pb (mW)	Recording groove	CNR (dB)	Erasure ratio (dB)	Recording power Pp/Pb (mW)
Region between grooves	52	33	7.0/3.0	Region between grooves	53	35	9.6/3.6
				Region on grooves	53	34	10.0/4.0
Region on grooves	52	34	7.5/3.5	Region between grooves	53	34	9.5/3.5
				Region on grooves	53	33	9.9/3.9

[0147]

Irrespective of whether the first information layer 11 is subjected to recording on grooves or between grooves, in the second information layer 20, satisfactory results of 30 dB ≤ erasure ratio, 50 dB ≤ CNR were obtained in recording on grooves and recording between grooves. Furthermore, satisfactory recording/erasing performance were obtained in both the first information layer 11 and the second information layer 20 similarly even in the case of recording between grooves and on grooves.

[0148]

(Example 11)

The recording cycle performance of the first information layer 11 and the second information layer 20 of the information recording medium 22 of the present invention was evaluated. The information recording medium in FIG. 1 was produced, and the dynamic evaluation system in FIG. 4 was used. In the present example, in the first recording layer forming step, $(Ge-Sn)_4Sb_2Te_7$, y = 10 atomic % was formed to 6 nm as the first recording

layer 4 in a krypton gas atmosphere, and even in the second recording layer forming step, $Ge_4Sb_2Te_7$ was formed to 12 nm as the second recording layer 14 in a krypton gas atmosphere. The other steps were the same as those in Example 3. The evaluation of the recording cycle performance was conducted by measuring a CNR of a 3T signal, and the number of times of recording up to when an initial CNR value was decreased by 3 dB was defined as recording cycle life. This is recording on grooves. (Table 9) shows evaluation results.

[0149]

[Table 9]

*: Atmospheric gas at a time of forming the first recording layer 4 and the second recording layer 14

Information recording medium No.	Gas *	First information layer 11 Cycle number	Second information layer 20 Cycle number
9–1	Krypton	150,000	200,000
3–18	Argon	100,000	150,000

[0150]

From the above results, the following was found: when the first recording layer 4 and the second recording layer 14 are formed in a krypton gas atmosphere, recording cycle performance is enhanced by 1.5 times compared with the case of forming them in an argon gas atmosphere.

[0151]

(Example 12)

In the present example, the relationship between the crystallization temperature and the crystallization time by the addition of Sb and Sn was checked. For measuring a crystallization temperature, a $(Ge\text{–}Sn)_4Sb_bTe_7$ film was formed to 6 nm and a Ge–N film was formed to 5 nm successively, as the first recording layer 4 on a quartz substrate. Five kinds of samples were produced in which the values of b and y were varied while a = 4 was set. The crystallization temperature is obtained by measuring the

transmittance of a sample while increasing the temperature of the sample with laser light, and is defined as a temperature at which the rapid decrease in transmittance involved in crystallization occurs. The crystallization temperature was measured for each sample. The crystallization time was measured by producing the thin film sample 28 in FIG. 5 in the same way as in Example 1, using the static evaluation system in FIG. 6. At this time, as the first recording layer 4, 5 kinds of samples with the same composition as that of a sample for measuring a crystallization temperature were prepared. The film thickness is 6 nm. (Table 10) shows measurement results.

[0152]

[Table 10]

b	First recording layer 4 composition y (atomic %)	Sample No.	Crystallization time (ns)	Sample No.	Crystallization temperature (°C)
2	0	1-4	90	10-3	200
2	10	1-24	50	10-4	180
3	10	10-1	55	10-5	195
2	15	1-34	20	10-6	170
3	15	10-2	22	10-7	185

[0153]

As is apparent from comparing samples 1-4, 1-24, and 1-34, when only Sn was added at b = 2, a crystallization time was shortened (90 ns → 50 ns → 20 ns), and along with this, a crystallization temperature also was decreased by 30°C (200°C → 180°C → 170°C). The decrease in crystallization temperature impairs the thermal stability of a recording mark. In contrast, when Sb was increased so as to attain b = 3, a crystallization time was shortened substantially in an equal rate (90 ns → 55 ns → 22 ns), whereas a decrease in crystallization temperature was 15°C (200°C → 195°C → 185°C). Thus, compared with the addition of only Sn, when Sb and Sn are added, a crystallization time can be shortened while

thermal stability is ensured.

[0154]

(Example 13)

Examples 3, 5, 6, 7, 8, 10, and 11 were conducted even with respect to the information recording medium 40 described in Embodiment 3. Consequently, similar results were obtained. The effects of the present invention are obtained irrespective of the forward step or the backward step.

[0155]

[Effects of the Invention]

As described above, according to the present invention, a material having a crystallization speed higher than that of a Ge–Sb–Te phase-change material is obtained, and the effect of realizing an excellent information recording medium is obtained, in which satisfactory recording/erasing performance is obtained and thermal stability of a recording mark is also obtained under the condition that the film thickness of the first recording layer is set to be very small (9 nm or less) so as to ensure the high transmittance of the first information layer, in two-layer high-density recording with a blue violet laser.

[Brief Description of the Drawings]

[Figure 1]

A partial cross-sectional view showing an example of an information recording medium of the present invention.

[Figure 2]

A triangle graph showing a composition range of a first recording layer of the present invention.

[Figure 3]

A partial cross-sectional view showing another example of the

information recording medium of the present invention.

[Figure 4]

A system diagram of a recording/reproducing system regarding the information recording medium of the present invention.

[Figure 5]

A partial cross-sectional view showing an example of a thin film sample for static evaluation.

[Figure 6]

A system diagram of a static evaluation system.

[Description of the Reference Numerals]

1 First substrate

2 First lower protective layer

3 First lower interface layer

4 First recording layer

5 First upper interface layer

6 First upper protective layer

7 First interface layer

8 First reflective layer

9 First uppermost interface layer

10 First uppermost protective layer

11, 42 First information layer

12 Second lower protective layer

13 Second lower interface layer

14 Second recording layer

15 Second upper interface layer

16 Second upper protective layer

17 Second interface layer

18 Second reflective layer

19 Second substrate

20 Second information layer

21 Intermediate layer

22, 40 Information recording medium

23, 30 Laser beam

24, 31 Objective lens

25, 32 Semiconductor laser

26, 33 Optical head

27 Spindle motor

28 Thin film sample

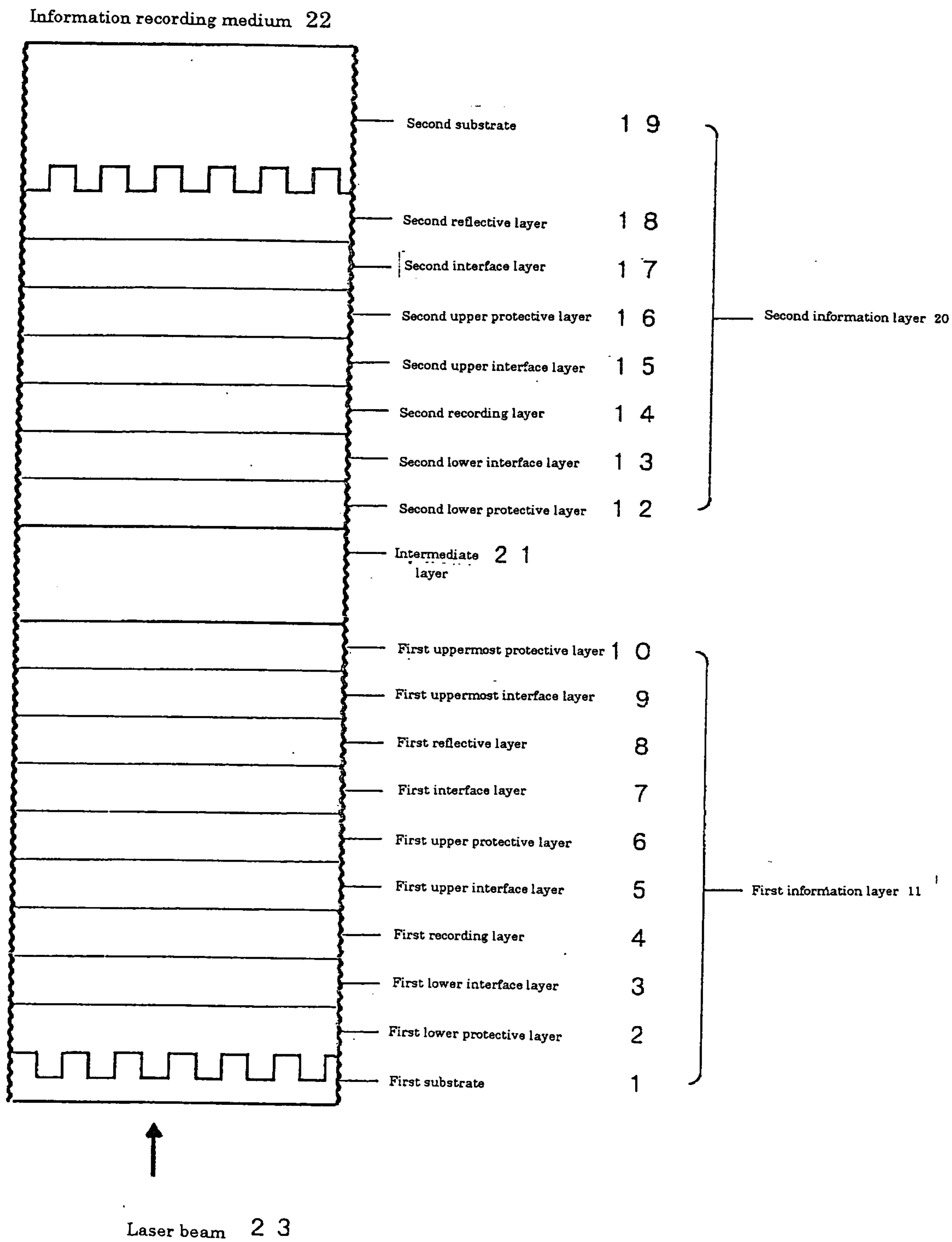
29 Thin film sample fixing stage

34 Substrate

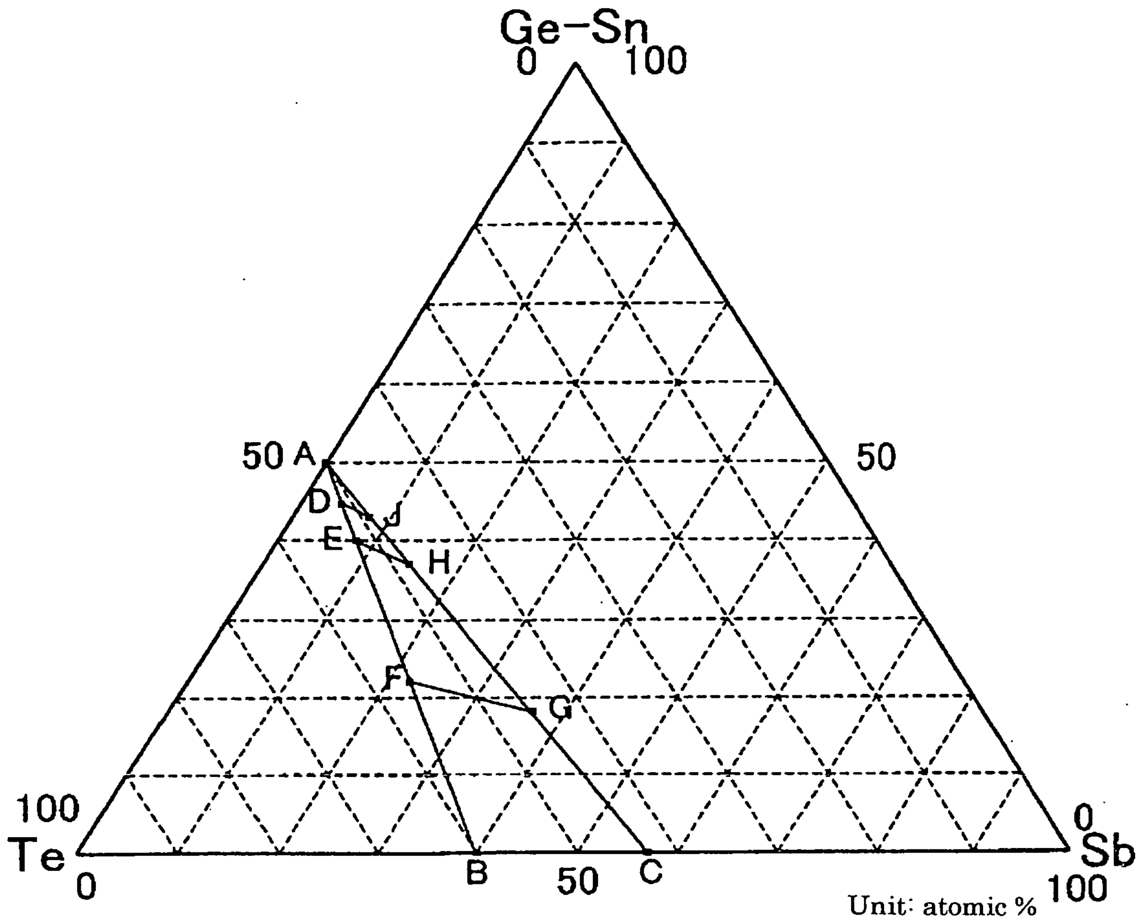
35 Dummy substrate

36, 41 Adhesive layer

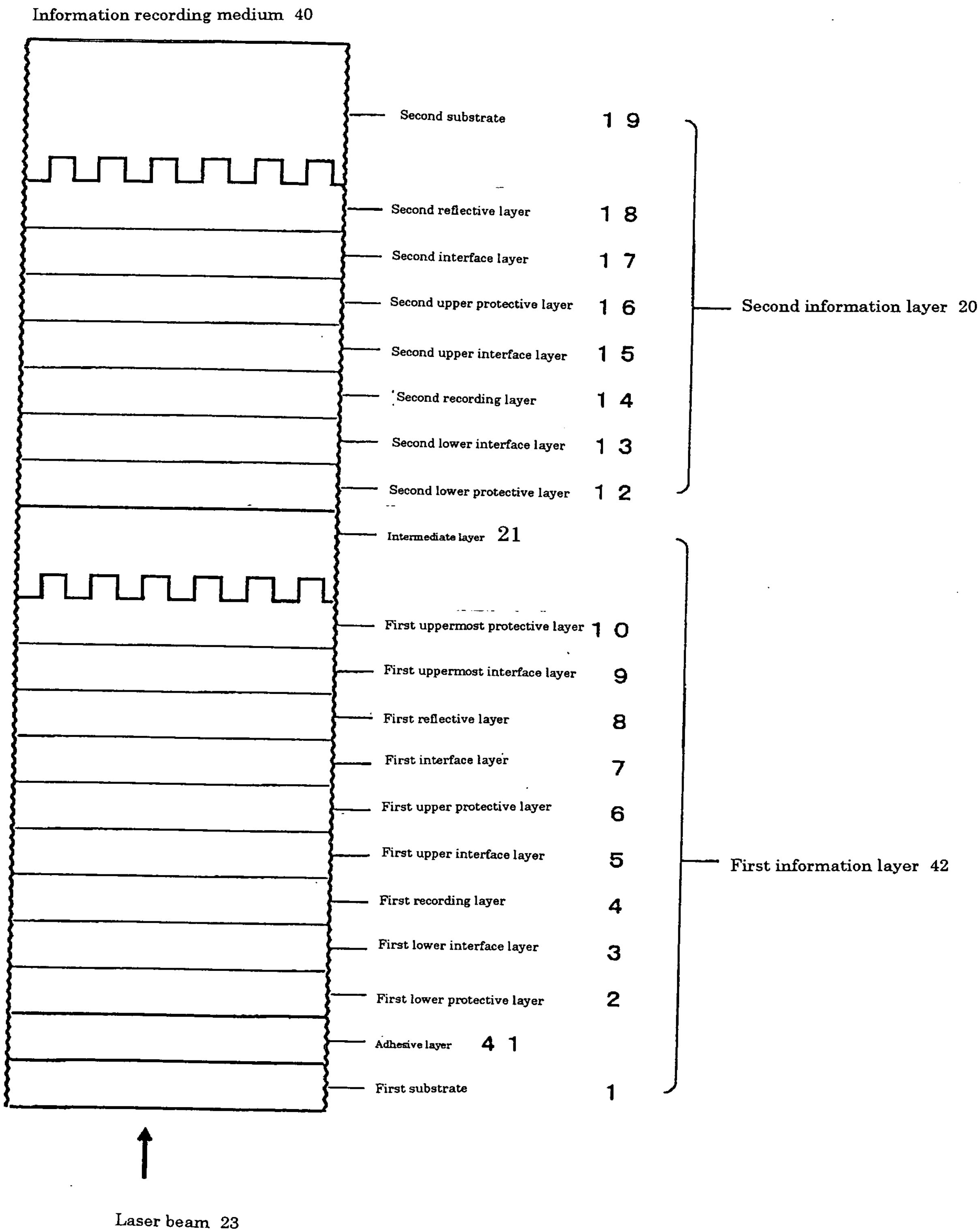
[Document Name] Drawings
[FIG. 1]



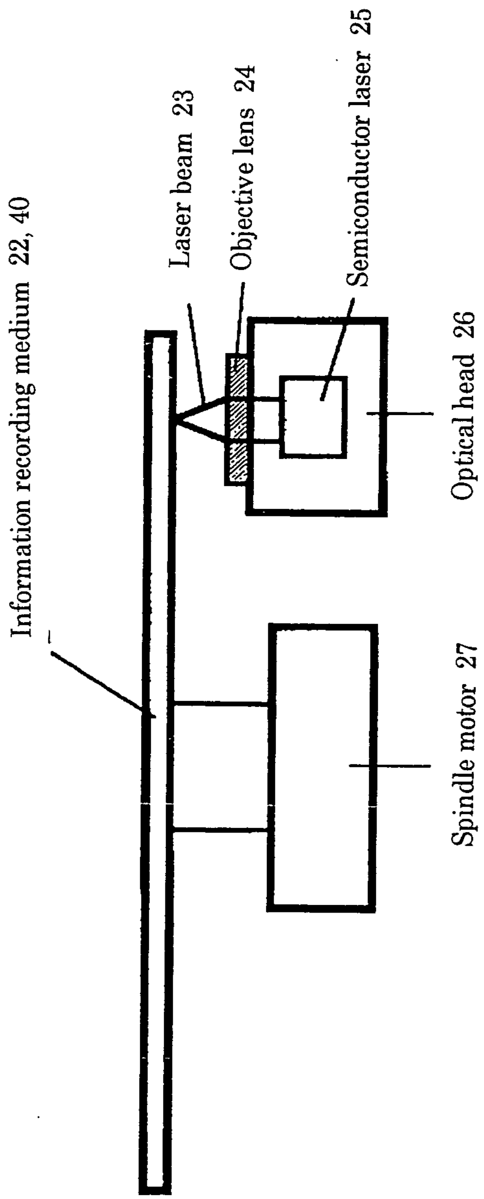
[FIG. 2]



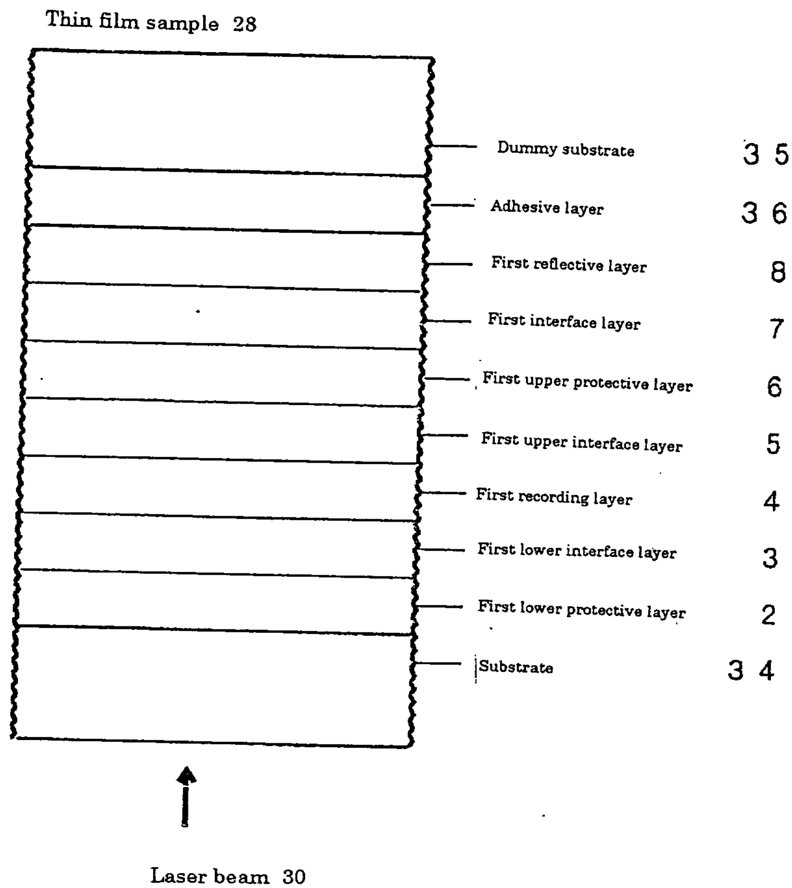
[FIG. 3]


Information recording medium 40
Second substrate 19
Second reflective layer 18
Second interface layer 17
Second upper protective layer 16
Second upper interface layer 15
Second recording layer 14
Second lower interface layer 13
Second lower protective layer 12
Second information layer 20
Intermediate layer 21
First uppermost protective layer 10
First uppermost interface layer 9
First reflective layer 8
First interface layer 7
First upper protective layer 6
First upper interface layer 5
First recording layer 4
First lower interface layer 3
First lower protective layer 2
First information layer 42
Adhesive layer 41
First substrate 1
Laser beam 23

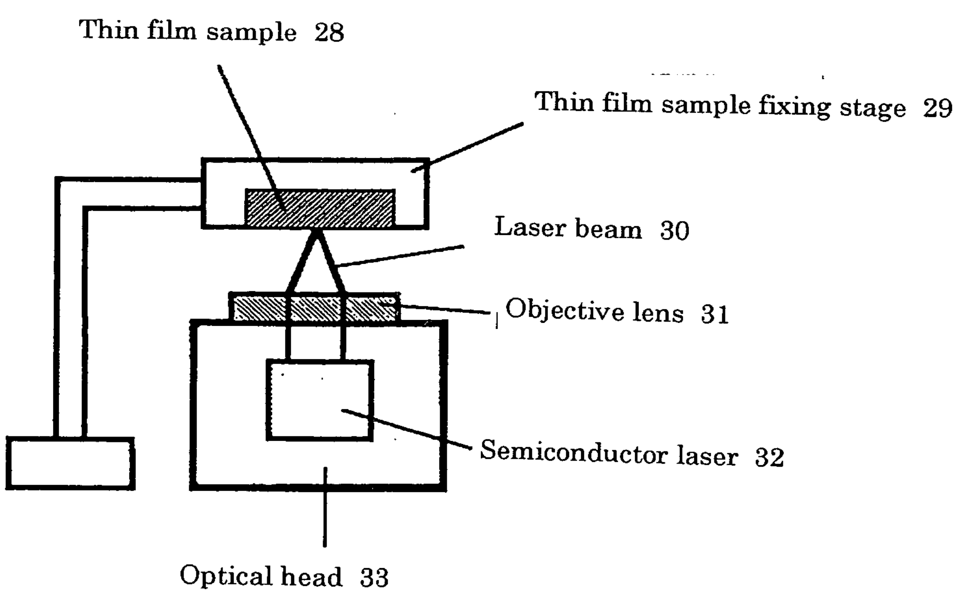
[FIG. 4]


Information recording medium 22, 40
Laser beam 23
Objective lens 24
Semiconductor laser 25
Optical head 26
Spindle motor 27

[FIG. 5]


Thin film sample 28
Dummy substrate 35
Adhesive layer 36
First reflective layer 8
First interface layer 7
First upper protective layer 6
First upper interface layer 5
First recording layer 4
First lower interface layer 3
First lower protective layer 2
Substrate 34
Laser beam 30

[FIG. 6]


Thin film sample 28
Thin film sample fixing stage 29
Laser beam 30
Objective lens 31
Semiconductor laser 32
Optical head 33

[Name of the Document] ABSTRACT

[Abstract]

[Objective] An excellent information recording medium is provided, in which a high transmittance is ensured in a blue-violet laser region and satisfactory recording/erasing performance is obtained in a first information layer on a laser incident side of an information recording medium with two-layered information layers formed thereon.

[Means for Solving the Problem] The composition of a first recording layer of an information recording medium is represented by $(Ge-Sn)_aSb_bTe_{3+a}$; the range of a and b is $2 \leq a \leq 22$, $2 \leq b \leq 4$; assuming that the concentration of Sn is y (atomic %), 0 atomic % $< y \leq 25$ atomic %; and the film thickness is 9 nm or less.

[Selected Figure] Figure 1